

# RESEARCH MEMORANDUM

ALTITUDE PERFORMANCE CHARACTERISTICS OF THE

J73-GE-1A TURBOJET ENGINE

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NATIONAL ADVISORY COMMITTEE  
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SUMMARY

An investigation was conducted in an altitude test chamber at the NACA Lewis laboratory to determine the performance characteristics of the J73-GE-1A turbojet engine. This model engine had a fixed-area exhaust nozzle and was the first of a series of J73 production engines. Performance data were obtained at simulated altitudes from 15,000 to 55,000 feet and at flight Mach numbers from approximately 0.07 to 1.01, which correspond to a range of compressor-inlet Reynolds number index values from 0.90 to 0.13.

Engine performance is presented in the form of engine pumping characteristics and combustion efficiency, from which the over-all performance may be calculated for any flight condition within the range of Reynolds number indices covered by the experimental data. Curves of net thrust and fuel flow, computed from these data, are presented as functions of true airspeed for four altitudes. Data are also included to enable the determination of thrust in flight.

INTRODUCTION

An investigation was conducted in an altitude test chamber at the NACA Lewis laboratory to determine the complete performance and operational characteristics of the J73 turbojet engine. The first phase of this program, which is reported herein, was an altitude-performance evaluation of the J73-GE-1A engine. Pending development of an improved control, this engine had a turbine-nozzle area ten percent larger than the design area for later engine models in order to avoid compressor surge during flight tests. The engine also incorporated variable compressor-inlet guide vanes to avoid part-speed surge. Throughout the investigation reported herein, however, the guide vanes were fixed at the design angle for the high engine speed range ( $13^\circ$  from axial).



The over-all altitude-performance characteristics of this engine are reported herein, and the component performance characteristics are given in reference 1. Data were obtained over a corrected engine speed range from 83 to 108 percent of rated speed, at altitudes from 15,000 to 55,000 feet, and at flight Mach numbers from approximately 0.07 to 1.01. The corresponding range of compressor-inlet Reynolds number index values was from 0.90 to 0.13.

The data are presented in the form of engine pumping characteristics to allow accurate calculation of engine performance at any operating or flight condition within the range covered by the experimental data. From the pumping characteristics, net thrust and fuel flow were calculated and are presented as functions of true airspeed for sea level and for altitudes of 15,000, 35,000, and 50,000 feet. A curve is also presented that will allow determination of thrust in flight by the measurement of ambient static pressure and total pressure in the exhaust nozzle.

#### INSTALLATION AND INSTRUMENTATION

Engine. - The J73-GE-1A turbojet engine (fig. 1) has variable compressor-inlet guide vanes, a 12-stage axial-flow compressor, ten cannular-type combustors, a two-stage turbine, and a fixed conical exhaust nozzle. At engine speeds above 6400 rpm, the variable inlet guide vanes are scheduled to be in the open position, with the tangent line between the leading and trailing edges at the blade tip forming an angle of  $13^\circ$  with the engine center line. At lower engine speeds, the guide vanes are scheduled to be in the closed position to avoid compressor surge, with the tangent line forming an angle of  $43^\circ$  with the engine center line. In addition to the inlet guide-vane variation, the turbine-nozzle area of the engine was increased to 110 percent of the design value for later engine models as a further precaution to avoid compressor surge until the engine control is refined. Compressor-outlet leakage and a small amount of bleed air are used for a balance-piston force at the front of the compressor and for cooling the turbine disks and the first-stage turbine nozzles. The exhaust nozzle (20.95-inch cold diameter) was sized to give the rated exhaust gas temperature of  $1215^\circ\text{F}$  at sea-level static conditions on a standard day at the rated engine speed of 7950 rpm. At these conditions, the rated engine thrust is 8630 pounds and the air flow is 142 pounds per second.

Altitude chamber. - The altitude chamber in which the engine was installed is shown schematically in figure 2. The test-chamber diameter is 14 feet. Atmospheric air or heated or refrigerated dry air can be supplied to the inlet of the test chamber. The engine was mounted on a movable test-bed, which was connected through linkages to a thrust-measuring cell of the null-type pressure-balanced diaphragm design. The thrust apparatus was calibrated by the dead-weight method with the engine and all connections in place.



The inlet or ram-pressure section of the chamber was separated from the exhaust or altitude-pressure section of the chamber by a bulkhead. A labyrinth-type frictionless seal was provided between the bulkhead and the engine-inlet duct to allow a slight amount of axial movement of the engine without binding. The bellmouth cowl was attached to the bulkhead and therefore transmitted no force to the engine-inlet duct.

Instrumentation. - The stations throughout the engine at which instrumentation was installed are shown in figure 3. Schematic drawings of the location of instrumentation at those stations that are pertinent in the determination of over-all engine performance are given in figure 4. All pressures were photographically recorded with either mercury- or alkazene-filled manometers. Temperatures were recorded by automatic self-balancing potentiometers. Engine speed was determined by a chronometric tachometer, and fuel flow was measured by means of calibrated rotameters.

### PROCEDURE

Performance data were obtained at simulated altitudes from 15,000 to 55,000 feet and flight Mach numbers from 0.07 to 1.01. Engine speed was varied from approximately 6400 rpm to the rated speed of 7950 rpm. Lower engine speeds, at which the inlet guide vanes are scheduled to be in the closed position, were not obtained because of special instrumentation, which prevented movement of the guide vanes. During this phase of the investigation, full control of inlet-air temperatures was not possible; however, temperatures were obtained in the range from  $-25^{\circ}$  to  $40^{\circ}$  F.

Fuel conforming to specification MIL-F-5624A grade JP-4 with a lower heating value of 18,700 Btu per pound and a hydrogen-carbon ratio of 0.168 was used throughout the investigation. Air flow was obtained from a survey of total and static pressures in the engine inlet at station 1 (fig. 3).

All symbols used in this report are defined in appendix A.

### RESULTS AND DISCUSSION

All the over-all performance data obtained in the investigation of the engine are compiled in table I in both nongeneralized and generalized form. It should be noted that the data in nongeneralized form are not adjusted for slight differences between the actual and the NACA standard values of inlet pressure, exhaust pressure, or engine-inlet temperature.



Pumping characteristics. - If the exhaust-nozzle pressure ratio of a turbojet engine is sufficiently high that the flow coefficient is constant with increasing nozzle pressure ratio, the engine pressure ratio at any constant temperature ratio is a function only of corrected engine speed, exhaust-nozzle area, and Reynolds number. Except for the effect of Reynolds number, changes in altitude or flight Mach number have no effect on the engine pressure ratio at constant values of engine temperature ratio. Accordingly for the engine discussed herein, the pumping characteristics are completely defined by curves of engine pressure ratio against engine temperature ratio for several constant values of Reynolds number index. These curves, coupled with associated curves that give the air flow and combustion efficiency at various operating conditions, completely define the performance of the engine.

The engine speeds and flight Mach numbers above which the exhaust nozzle was choked are defined in figure 5. The solid curve denotes the conditions at which the average exhaust-nozzle pressure ratio corresponded to the critical value. However, the exhaust-nozzle flow coefficient had not reached its maximum value at the critical pressure ratio and continued to increase up to an exhaust-nozzle pressure ratio of about 2.2. The dashed line denotes the conditions at which the exhaust nozzle was considered completely choked; that is, the pressure ratio was above critical and the flow coefficient had reached its maximum value. The pumping characteristics of figure 6, however, may be used with only small error in the region between the two curves, but they are not valid at nozzle pressure ratios below choking or for different exhaust-nozzle areas. The curves of figure 5 were determined from cross plots of exhaust-nozzle pressure ratio against corrected engine speed. The solid curve required some extrapolation inasmuch as only a few data points were in the region where the average exhaust-nozzle pressure ratio was below the critical value. The data were sufficient, however, to show that there was no appreciable Reynolds number effect on the solid curve.

The pumping characteristics for this engine (fig. 6) are given in the form of curves of engine pressure ratio as a function of engine temperature ratio for a wide range of Reynolds number indices. The altitudes and flight Mach numbers simulated in obtaining the different values of Reynolds number index are included in the symbol key. Lines of constant corrected engine speed, in percent of rated speed, have been superimposed; and a comparison with the curves of figure 5 shows that the exhaust nozzle was choked for virtually all the data of figure 6. Examination of the data reveals that it was immaterial what combination of altitude and flight Mach number was used to obtain a given value of Reynolds number index for the range of engine speeds presented. Although the data obtained at Reynolds number indices of 0.54 and 0.39 fall slightly out of order, examination of the bulk of the data shows that, at constant corrected engine speed, a progressive



increase in  $T_7/T_1$  and decrease in  $P_7/P_1$  occurred as the Reynolds number index was reduced. These changes result from reduced compressor efficiency and corrected air flow, as shown in reference 1.

Air flow. - The effect of Reynolds number index on engine air flow is shown in figure 7. Because of the data scatter, curves could not be drawn for Reynolds number index values of 0.16, 0.14, and 0.13. It is apparent, however, that the corrected air flow was reduced at a given corrected engine speed as the value of Reynolds number index was reduced.

Fuel flow. - Because of Reynolds number effects on component efficiencies and also because of variations in combustion efficiency with flight condition, the corrected fuel flow does not generalize to a single curve as a function of corrected engine speed. In order to permit the accurate determination of fuel flow, the combustion efficiency has been generalized as a function of the combustion parameter  $W_a T_7$  (fig. 8). This parameter is shown to be proportional to the familiar parameter  $PT/V$  in reference 2. Both the air flow  $W_a$  and the exhaust-gas temperature  $T_7$  can be obtained from figures 6 and 7, and the combustion efficiency can thus be determined. The ideal fuel-air ratio required to produce a given temperature rise from the engine inlet to the exhaust-nozzle inlet is given in figure 9 (data from ref. 3). The actual fuel-air ratio may be determined by dividing the ideal fuel-air ratio by the combustion efficiency. Fuel flow can then be obtained by multiplying the actual fuel-air ratio by the air flow.

Thrust. - By using the curves of figures 6 to 10 in conjunction with equation (5) of appendix B, jet thrust may be calculated on the basis of rake measurements at the exhaust-nozzle inlet at any value of Reynolds number index within the range covered. All values of rake jet thrust should be adjusted to actual thrust values by applying a thrust coefficient, that is, a calibration factor correlating rake thrust data with actual thrust data as determined from force measurements on the test-bed. However, inasmuch as the thrust coefficient was determined to be approximately 1.00 in this investigation, no adjustment was necessary. Net thrust can then be obtained from jet thrust by subtracting the momentum force of the inlet air. Also, the thrust may be calculated for various values of ram-pressure recovery or tail-pipe pressure loss by proper adjustment of the engine-inlet or exhaust pressures. A sample calculation is given in appendix C to illustrate the use of the curves.

Performance from pumping characteristics. - Net thrust and fuel flow for operation at standard NACA altitude conditions and 100-percent ram-pressure recovery have been calculated from the pumping characteristics and are shown as functions of true airspeed (fig. 10) for engine



speeds of 100, .95, 90, and 85 percent of rated engine speed. The portion of the curves denoted by the broken line required extrapolation of the pumping-characteristic curves and may therefore be less accurate than the solid curves. The dot-dash curve of figure 10 defines the condition of limiting exhaust-gas temperature. It is seen from figure 10(a) that the exhaust nozzle used was very slightly smaller than required for limiting temperature at rated engine speed; limiting temperature occurred at about 99 percent of rated speed. From figures 10(b) to (d), it is seen that the temperature-limited speed remained constant at about 99 percent of rated speed for all altitudes up to 50,000 feet. This unusual trend resulted from the compensating effects of decreasing ambient air temperature and reductions in compressor efficiency (ref. 1) as the altitude was increased. Net thrust exhibited the expected trend of first decreasing and then increasing as the true airspeed was increased from the static condition. Inasmuch as the fuel flow increased continuously with true airspeed, the specific fuel consumption also increased. For example, at rated sea-level static conditions the specific fuel consumption obtained from figure 10(a) was 0.956 pound of fuel per hour per pound of net thrust. At an airspeed of 650 knots, this value increased to 1.328.

The effects of increasing altitude on engine performance result from the following factors: (1) a reduction in ambient pressure, which reduces the engine air flow; (2) a reduction in ambient air temperature, which permits operation at higher corrected engine speeds with higher engine pressure and temperature ratios; (3) Reynolds number effects, which decrease the corrected air flow, the compressor efficiency, and sometimes the turbine efficiency; and (4) decreased combustion efficiency primarily due to reductions in combustor-inlet pressure. The first two effects can be predicted from sea-level data by use of the common correction factors  $\delta$  and  $\theta$ . Determination of the remaining altitude effects requires engine performance data at simulated altitude conditions. For example, if the performance of this engine were predicted at 95 percent of rated speed, an altitude of 50,000 feet, and an airspeed of 461 knots (Mach number of 0.8) on the basis of sea-level performance data, the net thrust would be about 1360 pounds compared with an actual value of 1367 pounds (see fig. 10(d)). The unusually close agreement of the predicted and actual thrusts for this engine is attributed to the increase in engine temperature ratio as the Reynolds number index was reduced; this increase balanced the detrimental effects of reduced Reynolds number on both engine air flow and compressor efficiency. The actual specific fuel consumption, however, was 1.161 pounds per hour per pound of net thrust, which is an increase of 3.4 percent over the predicted value of 1.122.

On the basis of the curves given in figures 6 to 9, the effects of nonstandard inlet-air temperature may also be calculated. For example, at take-off conditions and 99.4 percent of rated engine speed, the



effect of increasing the ambient air temperature from  $59^{\circ}$  to  $100^{\circ}$  F would be to reduce the thrust by 9.4 percent and increase the specific fuel consumption 1.1 percent.

In-flight thrust determination. - In order to facilitate the determination of engine thrust in flight and also to avoid using equation (5) in appendix B to determine the thrust of this engine configuration, jet thrust is given in figure 11 as a function of the quantity  $(1.26P_7 - p_0)$ . The correlation of these quantities is derived in reference 4. It is seen that the experimental correlation is good. For the exhaust-nozzle area used (20.95-inch cold diameter), the jet thrust is about 2.4 times the quantity  $(1.26P_7 - p_0)$ . If the exhaust nozzle is trimmed to a slightly different diameter, the thrust values given by figure 11 must be adjusted by multiplying the value from figure 11 by the ratio of the area actually used to the area used in this investigation. The use of figure 11 is also illustrated in the sample calculation of appendix C. It should be noted that this method of in-flight thrust determination is not valid when an ejector-exit configuration is employed, because of the effect of the ejector on the static pressure at the exhaust-nozzle outlet.

In using this method of measuring thrust, it is important to obtain an accurate average value of total pressure in the exhaust nozzle because of the existence of large total-pressure gradients. Typical total-pressure profiles are shown in figure 12 for several operating conditions. In this figure each symbol represents the average value obtained at a given radius from rakes located  $90^{\circ}$  apart (see fig. 4(b)). Examination of profiles for a large number of test points shows that an average from four total-pressure probes located at 78 percent of the nozzle radius gives the over-all average total pressure within  $\pm 0.3$  percent for this particular engine.

#### CONCLUDING REMARKS

From this investigation of the J73-GE-1A turbojet engine, sufficient data have been obtained and presented in the form of engine pumping characteristics to allow calculation of complete engine performance at all flight conditions with Reynolds number index values between 0.90 and 0.20 at corrected engine speeds above 6700 rpm. Although air flow data are not available, pumping-characteristic curves are also presented for Reynolds number index values of 0.16, 0.14, and 0.13 to aid in estimating the engine performance at extreme altitudes. Curves of net thrust and fuel flow, calculated from the pumping characteristics, are also given as functions of true airspeed for several altitudes.



For a given engine speed, the values of net thrust obtained with this engine at altitudes up to 50,000 feet agreed closely with the predicted values from sea-level data. However, the detrimental effects of increasing altitude on the over-all engine performance were evident in the higher specific fuel consumptions incurred at altitude compared with the values predicted from sea-level data. Specific fuel consumption also increased with increased flight Mach number or airspeed. The effect of having an ambient air temperature of 100° F instead of the standard 59° F at approximate take-off conditions was to reduce the net thrust of this engine by 9.4 percent and increase the specific fuel consumption by 1.1 percent.

Data are also presented to enable the determination of thrust in flight by measurements of total pressure at the exhaust-nozzle inlet and of ambient static pressure. Optimum immersion of the total-pressure probes and also possible errors due to the pressure profile are discussed briefly.

Lewis Flight Propulsion Laboratory  
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## APPENDIX A

## SYMBOLS

The following symbols are used in this report:

|           |                                                                                                           |
|-----------|-----------------------------------------------------------------------------------------------------------|
| A         | cross-sectional area, sq ft                                                                               |
| B         | force exerted on test-bed, lb                                                                             |
| $C_D$     | exhaust-nozzle flow coefficient                                                                           |
| $F_j$     | jet thrust, lb                                                                                            |
| $F_n$     | net thrust, lb                                                                                            |
| f         | fuel-air ratio                                                                                            |
| g         | acceleration due to gravity, 32.2 ft/sec <sup>2</sup>                                                     |
| h         | enthalpy, Btu/lb                                                                                          |
| $M_0$     | flight Mach number                                                                                        |
| N         | engine speed, rpm                                                                                         |
| P         | total pressure, lb/sq ft abs                                                                              |
| p         | static pressure, lb/sq ft abs                                                                             |
| R         | gas constant, 53.4 ft-lb/(lb)(°R)                                                                         |
| T         | total temperature, °R                                                                                     |
| t         | static temperature, °R                                                                                    |
| V         | velocity, ft/sec                                                                                          |
| $W_a$     | air flow, lb/sec                                                                                          |
| $W_f$     | fuel flow, lb/hr                                                                                          |
| $W_f/F_n$ | specific fuel consumption, lb/(hr)(lb net thrust)                                                         |
| $\gamma$  | ratio of specific heats                                                                                   |
| $\delta$  | ratio of engine-inlet total pressure to absolute static pressure of NACA standard atmosphere at sea level |



|                            |                                                                                                                             |
|----------------------------|-----------------------------------------------------------------------------------------------------------------------------|
| $\delta/\phi\sqrt{\theta}$ | Reynolds number index                                                                                                       |
| $\eta_b$                   | combustion efficiency                                                                                                       |
| $\theta$                   | ratio of absolute total temperature at engine inlet to absolute static temperature of NACA standard atmosphere at sea level |
| $\lambda$                  | $\frac{A_m + B}{m + 1}$ (see ref. 3), Btu/lb fuel                                                                           |
| $\rho$                     | density, slugs/cu ft                                                                                                        |
| $\phi$                     | ratio of absolute viscosity of air at engine inlet to absolute viscosity of NACA standard atmosphere at sea level           |

## Subscripts:

|   |                       |
|---|-----------------------|
| a | air                   |
| i | indicated             |
| R | rated                 |
| r | rake                  |
| s | scale                 |
| t | exhaust-nozzle throat |
| x | engine-inlet duct     |
| 0 | altitude test chamber |
| 1 | engine inlet          |
| 6 | turbine outlet        |
| 7 | exhaust-nozzle inlet  |



## APPENDIX B

## METHODS OF CALCULATION

Total temperatures were calculated from thermocouple-indicated temperatures with the equation

$$T = \frac{T_i \left(\frac{P}{p}\right)^{\frac{\gamma-1}{\gamma}}}{1 + \alpha \left[ \left(\frac{P}{p}\right)^{\frac{\gamma-1}{\gamma}} - 1 \right]} \quad (1)$$

An experimentally determined value of 0.85 was used for the thermocouple impact-recovery factor  $\alpha$ .

Air flow. - Engine-inlet air flow was determined from pressure and temperature instrumentation at station 1 by use of the equation

$$W_{a,1} = \rho_1 A_1 V_1 = A_1 \sqrt{\frac{2g}{R}} \left(\frac{P_1}{\sqrt{T_1}}\right) \sqrt{\left(\frac{\gamma_1}{\gamma_1 - 1}\right) \left(\frac{P_1}{P_1}\right)^{\frac{\gamma_1-1}{\gamma_1}} \left[ \left(\frac{P_1}{P_1}\right)^{\frac{\gamma_1-1}{\gamma_1}} - 1 \right]} \quad (2)$$

The various compressor-outlet bleed flows and compressor-leakage air flow were determined to be about 2 percent of the engine-inlet air flow. All bleed and leakage flows rejoined the main-stream flow before reaching the exhaust nozzle.

Combustion efficiency. - Combustion efficiency is defined as the ratio of the actual enthalpy rise through the combustor to the theoretical maximum enthalpy rise. The following equation was used to calculate combustion efficiency:

$$\eta_b = \frac{h_{a,7} + f\lambda_7 - h_{a,1}}{18,700f} \quad (3)$$

Thrust coefficient. - The nozzle thrust coefficient, which was used to adjust rake thrust to actual thrust, was calculated as the ratio of the jet thrust obtained from force measurements on the test



bed to the rake jet thrust. Thrust based on force measurements (scale thrust) was obtained from the equation

$$F_{j,s} = B + \frac{W_{a,l} V_x}{g} + A_x(p_x - p_0) \quad (4)$$

The ideal or rake jet thrust, based on the survey at the exhaust-nozzle inlet, was obtained from the following expression:

$$F_{j,r} = (1+f)W_{a,l} \sqrt{\frac{2R}{g} \frac{r_7 T_7}{(r_7 - 1)}} \left[ 1 - \left( \frac{p_t}{p_7} \right)^{\frac{r_7 - 1}{r_7}} \right] + C_D A_t (p_t - p_0) \quad (5)$$

When the jet velocity is subsonic,  $\left[ p_7/p_0 < \left( \frac{r+1}{2} \right)^{\frac{r}{r-1}} \right]$ , and  $p_t = p_0$ , equation (5) becomes

$$F_{j,r} = (1+f)W_{a,l} \sqrt{\frac{2R}{g} \frac{r_7 T_7}{(r_7 - 1)}} \left[ 1 - \left( \frac{p_0}{p_7} \right)^{\frac{r_7 - 1}{r_7}} \right] \quad (6)$$

Net thrust was obtained by subtracting the equivalent momentum of the air at the engine inlet from the jet thrust

$$F_{n,s} = F_{j,s} - \frac{W_{a,l} V_0}{g} \quad (7)$$

where  $V_0$  is given by the equation

$$V_0 = \sqrt{\frac{2r_1 g R T_1}{r_1 - 1}} \left[ 1 - \left( \frac{p_0}{p_1} \right)^{\frac{r_1 - 1}{r_1}} \right] \quad (8)$$

with complete ram-pressure recovery assumed.

The ratio of hot exhaust-nozzle area to cold exhaust-nozzle area was taken as 1.01 for all calculations herein.



## APPENDIX C

## SAMPLE CALCULATIONS

In order to illustrate the use of the engine pumping characteristics, a problem is assumed at random as follows:

It is desired to determine the net thrust and specific fuel consumption of a J73-GE-1A engine operating in an airplane at the following conditions:

|                                             |        |
|---------------------------------------------|--------|
| Pressure altitude, ft                       | 38,000 |
| Ambient pressure, $p_0$ , lb/sq ft          | 431    |
| Flight Mach number, $M_0$                   | 0.80   |
| Ambient air temperature, $^{\circ}\text{F}$ | 0      |
| Engine speed, $N$ , rpm                     | 7800   |
| Ram-pressure recovery                       | 0.95   |

It is assumed that for the airplane in question a nonstandard tail pipe is required such that 0.04 of the total pressure is lost between the turbine outlet and the exhaust nozzle.

Engine-inlet conditions are calculated as follows:

$$p_0 \text{ (given)} = 431 \text{ lb/sq ft}$$

$$T_1 = t_0 \left( 1 + \frac{\gamma-1}{2} M_0^2 \right) = 460 \left[ 1 + 0.2(0.8)^2 \right] = 519^{\circ} \text{ R}$$

$$\theta = T_1/519 = 1.00$$

$$N/\sqrt{\theta} = 7800 \text{ rpm}$$

$$P_1 = p_0 + 0.95p_0 \left[ (1 + 0.2M_0^2)^{3.5} - 1 \right] = 645.8 \text{ lb/sq ft}$$

$$\phi = 1.00, \text{ since } \theta = 1.0$$

$$\delta = 645.8/2116 = 0.305$$

$$\delta/\phi\sqrt{\theta} = \delta = 0.305$$

$$\frac{N/\sqrt{\theta}}{(N)_R} = \frac{7800}{7950} = 0.981$$

From these values, the engine temperature ratio and pressure ratio may be determined as follows:

At 98.1 percent of rated corrected engine speed and at a Reynolds number index of 0.305, the engine total-pressure ratio and engine total-temperature ratio are given in figure 6 as approximately 2.15 and 3.21, respectively. The exhaust-gas temperature is then

$$T_7 = 3.21T_1 = 1666^\circ \text{ R}$$

and the total pressure for the standard engine at the exhaust nozzle would be

$$P_7 = 2.15P_1 = 1388 \text{ lb/sq ft}$$

In order to allow calculations for engines with nonstandard tail-pipe installations, the tail-pipe pressure losses for the standard tail pipe are presented in figure 13 as a basis for a correction factor. For the engine in question, the exhaust-nozzle total pressure is then

$$P_7 = 1388 \frac{1 - 0.040}{1 - 0.028} = 1371 \text{ lb/sq ft abs}$$

where 0.028 is the value of  $(P_6 - P_7)/P_6$  for the standard engine and 0.040 is the value for the engine in question.

From figure 7, the corrected air flow at a corrected speed of 7800 rpm is

$$\frac{W_a \sqrt{\theta}}{\delta} = 137.4 \text{ lb/sec}$$

and, since  $\theta$  equals unity,

$$W_a = 137.4 \frac{645.8}{2116} = 41.9 \text{ lb/sec}$$

The temperature rise across the engine ( $T_7 - T_1$ ) is  $(1666^\circ - 519^\circ)$  or  $1147^\circ \text{ R}$ . From figure 9, the ideal fuel-air ratio is 0.0161. The combustion parameter  $W_a T_7$  is  $(41.9 \times 1666)$  or  $6.98 \times 10^4$ . Hence, from figure 8, the actual combustion efficiency is 0.96. The actual fuel-air ratio is then  $(0.0161/0.96)$  or 0.0168. The engine fuel flow is then given by the product of the air flow and the fuel-air ratio



$$W_f = W_a(f) = 41.9(0.0168) = 0.704 \text{ lb/sec}$$

or

$$W_f = 2535 \text{ lb/hr}$$

The jet thrust of the engine may be determined rapidly by the use of figure 11. The value of  $(1.26P_7 - p_0)$  is 1296 pounds per square foot, and hence the jet thrust is given in figure 11 as 3090 pounds.

Jet thrust may be determined with more precision by the use of equation (5). At a temperature of  $1666^\circ \text{ R}$  and a fuel-air ratio of 0.0168,  $\gamma_7$  is 1.330. The value of the static pressure  $p_t$  at the throat of the exhaust nozzle may be determined from the following expression for critical pressure ratio:

$$\frac{P_7}{p_t} = \left( \frac{\gamma_7 + 1}{2} \right)^{\frac{\gamma_7}{\gamma_7 - 1}} = 1.850$$

Hence,  $p_t$  is 741 pounds per square foot. Substitution of these quantities into equation (5) results in a jet-thrust value of 3135 pounds. The thrust coefficient is 1.00; hence no correction is required. Net thrust is obtained by subtracting the momentum of the inlet air. Therefore,

$$F_n = F_j - W_a V_0 / g = 2039 \text{ lb}$$

since

$$V_0 = M_0 \sqrt{\gamma g R T_0} = 842 \text{ ft/sec}$$

and

$$W_a V_0 / g = (41.9)(842) / 32.2 = 1096 \text{ lb}$$

The specific fuel consumption is  $2535 / 2039 = 1.24$  pounds of fuel per hour per pound of net thrust.

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TABLE I. - ENGINE PERFORMANCE DATA FOR J73-GE-1A TURBOJET ENGINE

| Run | Altitude,<br>ft | Reynolds<br>number<br>index,<br>$\frac{\delta_1}{\phi_1 \sqrt{\theta_1}}$ | Ram-<br>pressure<br>ratio,<br>$P_1/P_0$ | Flight<br>Mach<br>number,<br>$M_0$ | Tank<br>static<br>pressure,<br>$P_0$ ,<br>lb<br>sq ft abs | Engine<br>speed,<br>N,<br>rpm | Fuel<br>flow,<br>$W_f$ ,<br>lb/hr | Engine-<br>inlet-duct<br>static<br>pressure,<br>$P_x$ ,<br>lb<br>sq ft abs | Engine-<br>inlet<br>total<br>pressure,<br>$P_1$ ,<br>lb<br>sq ft abs | Engine-<br>inlet<br>total<br>temper-<br>ature,<br>$T_1$ ,<br>°R | Turbine-<br>outlet<br>total<br>pressure,<br>$P_6$ ,<br>lb<br>sq ft abs | Exhaust-<br>nozzle-<br>inlet<br>total<br>pressure,<br>$P_7$ ,<br>lb<br>sq ft abs | Exhaust-<br>gas total<br>tempera-<br>ture,<br>$T_7$ ,<br>°R | Engine<br>total-<br>pressure<br>ratio,<br>$P_7/P_1$ | Engine<br>total-<br>temper-<br>ature<br>ratio,<br>$T_7/T_1$ |
|-----|-----------------|---------------------------------------------------------------------------|-----------------------------------------|------------------------------------|-----------------------------------------------------------|-------------------------------|-----------------------------------|----------------------------------------------------------------------------|----------------------------------------------------------------------|-----------------------------------------------------------------|------------------------------------------------------------------------|----------------------------------------------------------------------------------|-------------------------------------------------------------|-----------------------------------------------------|-------------------------------------------------------------|
| 1   | 15,000          | 0.895                                                                     | 1.528                                   | 0.803                              | 1185                                                      | 7841                          | 7500                              | 1707                                                                       | 1811                                                                 | 499                                                             | 4191                                                                   | 4087                                                                             | 1644                                                        | 2.257                                               | 3.335                                                       |
| 2   |                 | .893                                                                      | 1.511                                   | .792                               | 1194                                                      | 7737                          | 7120                              | 1703                                                                       | 1804                                                                 | 499                                                             | 4113                                                                   | 4003                                                                             | 1614                                                        | 2.219                                               | 3.234                                                       |
| 3   |                 | .899                                                                      | 1.520                                   | .798                               | 1191                                                      | 7614                          | 6680                              | 1711                                                                       | 1810                                                                 | 498                                                             | 3996                                                                   | 3885                                                                             | 1564                                                        | 2.146                                               | 3.141                                                       |
| 4   |                 | .898                                                                      | 1.513                                   | .793                               | 1193                                                      | 7216                          | 5380                              | 1717                                                                       | 1805                                                                 | 498                                                             | 3582                                                                   | 3484                                                                             | 1411                                                        | 1.930                                               | 2.833                                                       |
| 5   |                 | .910                                                                      | 1.533                                   | .806                               | 1192                                                      | 6581                          | 3370                              | 1760                                                                       | 1827                                                                 | 498                                                             | 2840                                                                   | 2787                                                                             | 1176                                                        | 1.525                                               | 2.361                                                       |
| 6   | 15,000          | 0.749                                                                     | 1.269                                   | 0.594                              | 1193                                                      | 7822                          | 6160                              | 1429                                                                       | 1514                                                                 | 499                                                             | 3509                                                                   | 3396                                                                             | 1660                                                        | 2.243                                               | 3.307                                                       |
| 7   |                 | .749                                                                      | 1.277                                   | .602                               | 1179                                                      | 7778                          | 6125                              | 1421                                                                       | 1506                                                                 | 497                                                             | 3490                                                                   | 3393                                                                             | 1628                                                        | 2.253                                               | 3.276                                                       |
| 8   |                 | .761                                                                      | 1.284                                   | .609                               | 1184                                                      | 7616                          | 5670                              | 1437                                                                       | 1520                                                                 | 495                                                             | 3364                                                                   | 3272                                                                             | 1570                                                        | 2.153                                               | 3.172                                                       |
| 9   |                 | .750                                                                      | 1.279                                   | .604                               | 1181                                                      | 7222                          | 4530                              | 1438                                                                       | 1511                                                                 | 497                                                             | 2999                                                                   | 2916                                                                             | 1422                                                        | 1.930                                               | 2.861                                                       |
| 10  |                 | .759                                                                      | 1.272                                   | .597                               | 1191                                                      | 6680                          | 3120                              | 1456                                                                       | 1515                                                                 | 496                                                             | 2473                                                                   | 2426                                                                             | 1220                                                        | 1.601                                               | 2.460                                                       |
| 11  | 15,000          | 0.651                                                                     | 1.102                                   | 0.376                              | 1197                                                      | 7828                          | 5450                              | 1247                                                                       | 1319                                                                 | 499                                                             | 3048                                                                   | 2966                                                                             | 1659                                                        | 2.249                                               | 3.325                                                       |
| 12  |                 | .661                                                                      | 1.112                                   | .392                               | 1187                                                      | 7212                          | 3955                              | 1258                                                                       | 1320                                                                 | 495                                                             | 2629                                                                   | 2557                                                                             | 1428                                                        | 1.937                                               | 2.885                                                       |
| 13  |                 | .668                                                                      | 1.118                                   | .403                               | 1187                                                      | 6411                          | 2345                              | 1284                                                                       | 1327                                                                 | 493                                                             | 2019                                                                   | 1980                                                                             | 1172                                                        | 1.492                                               | 2.377                                                       |
| 14  | 15,000          | 0.594                                                                     | 1.006                                   | 0.092                              | 1183                                                      | 7795                          | 4855                              | 1131                                                                       | 1190                                                                 | 494                                                             | 2729                                                                   | 2657                                                                             | 1644                                                        | 2.233                                               | 3.328                                                       |
| 15  |                 | .588                                                                      | .994                                    | -----                              | 1189                                                      | 7598                          | 4370                              | 1126                                                                       | 1182                                                                 | 496                                                             | 2609                                                                   | 2539                                                                             | 1578                                                        | 2.148                                               | 3.181                                                       |
| 16  |                 | .601                                                                      | 1.002                                   | .055                               | 1187                                                      | 7222                          | 3600                              | 1139                                                                       | 1189                                                                 | 492                                                             | 2391                                                                   | 2324                                                                             | 1440                                                        | 1.955                                               | 2.927                                                       |
| 17  |                 | .596                                                                      | 1.010                                   | .118                               | 1178                                                      | 6407                          | 2250                              | 1155                                                                       | 1190                                                                 | 493                                                             | 1886                                                                   | 1852                                                                             | 1221                                                        | 1.556                                               | 2.477                                                       |
| 18  | 25,000          | 0.590                                                                     | 1.526                                   | 0.802                              | 781                                                       | 7839                          | 4900                              | 1124                                                                       | 1192                                                                 | 495                                                             | 2759                                                                   | 2682                                                                             | 1654                                                        | 2.250                                               | 3.341                                                       |
| 19  |                 | .593                                                                      | 1.524                                   | .800                               | 780                                                       | 7786                          | 4770                              | 1121                                                                       | 1189                                                                 | 493                                                             | 2735                                                                   | 2658                                                                             | 1633                                                        | 2.235                                               | 3.312                                                       |
| 20  |                 | .595                                                                      | 1.537                                   | .809                               | 778                                                       | 7627                          | 4235                              | 1131                                                                       | 1196                                                                 | 494                                                             | 2636                                                                   | 2561                                                                             | 1576                                                        | 2.141                                               | 3.190                                                       |
| 21  |                 | .589                                                                      | 1.529                                   | .803                               | 777                                                       | 6551                          | 2175                              | 1144                                                                       | 1188                                                                 | 495                                                             | 1843                                                                   | 1797                                                                             | 1176                                                        | 1.513                                               | 2.376                                                       |
| 22  | 35,000          | 0.550                                                                     | 1.912                                   | 1.009                              | 486                                                       | 7875                          | 4480                              | 872                                                                        | 929                                                                  | 435                                                             | 2388                                                                   | 2336                                                                             | 1642                                                        | 2.515                                               | 3.775                                                       |
| 23  |                 | .551                                                                      | 1.898                                   | 1.003                              | 490                                                       | 7617                          | 3930                              | 874                                                                        | 930                                                                  | 436                                                             | 2268                                                                   | 2217                                                                             | 1540                                                        | 2.384                                               | 3.532                                                       |
| 24  |                 | .541                                                                      | 1.912                                   | 1.009                              | 489                                                       | 7214                          | 3240                              | 883                                                                        | 935                                                                  | 440                                                             | 2074                                                                   | 2018                                                                             | 1398                                                        | 2.158                                               | 3.177                                                       |
| 25  |                 | .531                                                                      | 1.912                                   | 1.009                              | 491                                                       | 6678                          | 2300                              | 897                                                                        | 939                                                                  | 449                                                             | 1728                                                                   | 1688                                                                             | 1217                                                        | 1.798                                               | 2.710                                                       |
| 26  | 35,000          | 0.412                                                                     | 1.549                                   | 0.816                              | 495                                                       | 7848                          | 3340                              | 724                                                                        | 767                                                                  | 468                                                             | 1827                                                                   | 1780                                                                             | 1665                                                        | 2.321                                               | 3.558                                                       |
| 27  |                 | .410                                                                      | 1.527                                   | .802                               | 490                                                       | 7807                          | 3290                              | 704                                                                        | 748                                                                  | 461                                                             | 1812                                                                   | 1775                                                                             | 1639                                                        | 2.373                                               | 3.555                                                       |
| 28  |                 | .377                                                                      | 1.538                                   | .809                               | 489                                                       | 7797                          | 3090                              | 710                                                                        | 752                                                                  | 491                                                             | 1732                                                                   | 1684                                                                             | 1661                                                        | 2.239                                               | 3.383                                                       |
| 29  |                 | .373                                                                      | 1.548                                   | .816                               | 487                                                       | 7617                          | 2800                              | 714                                                                        | 754                                                                  | 497                                                             | 1651                                                                   | 1601                                                                             | 1595                                                        | 2.123                                               | 3.209                                                       |
| 30  |                 | .408                                                                      | 1.538                                   | .809                               | 489                                                       | 7616                          | 3010                              | 709                                                                        | 752                                                                  | 465                                                             | 1739                                                                   | 1699                                                                             | 1569                                                        | 2.259                                               | 3.374                                                       |
| 31  |                 | .402                                                                      | 1.532                                   | .806                               | 491                                                       | 7436                          | 2770                              | 711                                                                        | 752                                                                  | 471                                                             | 1689                                                                   | 1641                                                                             | 1517                                                        | 2.182                                               | 3.221                                                       |
| 32  |                 | .401                                                                      | 1.548                                   | .816                               | 484                                                       | 7214                          | 2400                              | 711                                                                        | 749                                                                  | 474                                                             | 1555                                                                   | 1516                                                                             | 1434                                                        | 2.024                                               | 3.025                                                       |
| 33  |                 | .367                                                                      | 1.544                                   | .813                               | 493                                                       | 7174                          | 2205                              | 726                                                                        | 761                                                                  | 504                                                             | 1466                                                                   | 1422                                                                             | 1431                                                        | 1.869                                               | 2.839                                                       |
| 34  |                 | .388                                                                      | 1.546                                   | .815                               | 485                                                       | 6676                          | 1666                              | 720                                                                        | 750                                                                  | 482                                                             | 1273                                                                   | 1238                                                                             | 1242                                                        | 1.651                                               | 2.577                                                       |
| 35  | 49,000          | 0.247                                                                     | 1.787                                   | 0.950                              | 254                                                       | 7699                          | 1930                              | 431                                                                        | 454                                                                  | 468                                                             | 1060                                                                   | 1045                                                                             | 1619                                                        | 2.302                                               | 3.459                                                       |
| 36  |                 | .242                                                                      | 1.754                                   | .934                               | 260                                                       | 7623                          | 1880                              | 430                                                                        | 456                                                                  | 470                                                             | 1051                                                                   | 1035                                                                             | 1594                                                        | 2.270                                               | 3.391                                                       |
| 37  |                 | .238                                                                      | 1.796                                   | .955                               | 251                                                       | 7220                          | 1500                              | 428                                                                        | 449                                                                  | 475                                                             | 925                                                                    | 910                                                                              | 1460                                                        | 2.027                                               | 3.073                                                       |
| 38  |                 | .250                                                                      | 1.761                                   | .937                               | 259                                                       | 6964                          | 1340                              | 436                                                                        | 456                                                                  | 466                                                             | 889                                                                    | 876                                                                              | 1364                                                        | 1.921                                               | 2.927                                                       |
| 39  |                 | .229                                                                      | 1.739                                   | .926                               | 257                                                       | 6680                          | 1050                              | 439                                                                        | 447                                                                  | 486                                                             | 756                                                                    | 742                                                                              | 1269                                                        | 1.660                                               | 2.611                                                       |
| 40  | 55,000          | 0.191                                                                     | 1.961                                   | 1.031                              | 179                                                       | 7661                          | 1530                              | 331                                                                        | 351                                                                  | 465                                                             | 820                                                                    | 808                                                                              | 1630                                                        | 2.302                                               | 3.505                                                       |
| 41  |                 | .195                                                                      | 1.816                                   | .965                               | 197                                                       | 7508                          | 1441                              | 349                                                                        | 356                                                                  | 461                                                             | 807                                                                    | 794                                                                              | 1572                                                        | 2.230                                               | 3.410                                                       |
| 42  |                 | .195                                                                      | 1.940                                   | 1.022                              | 183                                                       | 7223                          | 1270                              | 345                                                                        | 355                                                                  | 464                                                             | 751                                                                    | 741                                                                              | 1476                                                        | 2.087                                               | 3.181                                                       |
| 43  |                 | .193                                                                      | 1.873                                   | .992                               | 189                                                       | 6958                          | 1075                              | 346                                                                        | 354                                                                  | 463                                                             | 692                                                                    | 683                                                                              | 1381                                                        | 1.929                                               | 2.983                                                       |
| 44  |                 | .205                                                                      | 1.994                                   | 1.045                              | 181                                                       | 6674                          | 892                               | 342                                                                        | 361                                                                  | 464                                                             | 633                                                                    | 624                                                                              | 1278                                                        | 1.729                                               | 2.754                                                       |



TABLE I. - Concluded. ENGINE PERFORMANCE DATA FOR J73-GE-1A TURBOJET ENGINE

| Run | Air flow,<br>$W_a$ ,<br>lb/sec | Fuel-air<br>ratio,<br>f | Jet<br>thrust,<br>$F_j$ ,<br>lb | Net<br>thrust,<br>$F_n$ ,<br>lb | Specific fuel<br>consumption,<br>$W_f/F_n$ ,<br>lb<br>(hr)(lb thrust) | Corrected<br>engine<br>speed,<br>$N/\sqrt{\theta_1}$ ,<br>rpm | Corrected<br>air flow,<br>$W_a\sqrt{\theta_1}$ ,<br>lb/sec | Corrected<br>fuel<br>flow,<br>$W_f/\theta_1\sqrt{\theta_1}$ ,<br>lb/hr | Corrected<br>fuel-air<br>ratio,<br>f/ $\theta_1$ | Corrected<br>jet<br>thrust,<br>$F_j/\theta_1$ ,<br>lb | Corrected<br>net<br>thrust,<br>$F_n/\theta_1$ ,<br>lb | Corrected specific<br>fuel<br>consumption,<br>$W_f/F_n\sqrt{\theta_1}$ ,<br>lb<br>(hr)(lb thrust) | Corrected exhaust-<br>gas tem-<br>perature,<br>$T_7/\theta_1$ ,<br>$^{\circ}R$ |
|-----|--------------------------------|-------------------------|---------------------------------|---------------------------------|-----------------------------------------------------------------------|---------------------------------------------------------------|------------------------------------------------------------|------------------------------------------------------------------------|--------------------------------------------------|-------------------------------------------------------|-------------------------------------------------------|---------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| 1   | 124.3                          | 0.0168                  | 9530                            | 6335                            | 1.184                                                                 | 7996                                                          | 142.3                                                      | 8933                                                                   | 0.0175                                           | 11,170                                                | 7400                                                  | 1.208                                                                                             | 1731                                                                           |
| 2   | 123.0                          | .0161                   | 9206                            | 6085                            | 1.170                                                                 | 7890                                                          | 141.4                                                      | 8517                                                                   | .0167                                            | 10,799                                                | 7138                                                  | 1.193                                                                                             | 1679                                                                           |
| 3   | 121.7                          | .0153                   | 8877                            | 5769                            | 1.158                                                                 | 7773                                                          | 139.3                                                      | 7972                                                                   | .0159                                            | 10,377                                                | 6744                                                  | 1.182                                                                                             | 1630                                                                           |
| 4   | 114.7                          | .0130                   | 7522                            | 4609                            | 1.167                                                                 | 7367                                                          | 131.7                                                      | 6437                                                                   | .0135                                            | 8,816                                                 | 5402                                                  | 1.191                                                                                             | 1470                                                                           |
| 5   | 101.7                          | .0092                   | 5440                            | 2817                            | 1.196                                                                 | 6719                                                          | 115.3                                                      | 3984                                                                   | .0096                                            | 6,300                                                 | 3262                                                  | 1.221                                                                                             | 1225                                                                           |
| 6   | 103.8                          | 0.0165                  | 7475                            | 5448                            | 1.131                                                                 | 7977                                                          | 142.4                                                      | 8782                                                                   | 0.0172                                           | 10,450                                                | 7616                                                  | 1.153                                                                                             | 1716                                                                           |
| 7   | 103.3                          | .0165                   | 7378                            | 5340                            | 1.147                                                                 | 7948                                                          | 142.1                                                      | 8793                                                                   | .0172                                            | 10,366                                                | 7503                                                  | 1.172                                                                                             | 1700                                                                           |
| 8   | 102.8                          | .0153                   | 7051                            | 5003                            | 1.133                                                                 | 7798                                                          | 139.8                                                      | 8082                                                                   | .0160                                            | 9,815                                                 | 6964                                                  | 1.160                                                                                             | 1647                                                                           |
| 9   | 96.0                           | .0131                   | 5965                            | 4065                            | 1.114                                                                 | 7380                                                          | 131.5                                                      | 6481                                                                   | .0137                                            | 8,351                                                 | 5691                                                  | 1.138                                                                                             | 1485                                                                           |
| 10  | 86.9                           | .0100                   | 4438                            | 2738                            | 1.140                                                                 | 6833                                                          | 118.7                                                      | 4459                                                                   | .0105                                            | 6,200                                                 | 3825                                                  | 1.166                                                                                             | 1276                                                                           |
| 11  | 90.2                           | 0.0168                  | 6156                            | 5019                            | 1.086                                                                 | 7983                                                          | 141.9                                                      | 8915                                                                   | 0.0175                                           | 9,874                                                 | 8050                                                  | 1.107                                                                                             | 1725                                                                           |
| 12  | 84.0                           | .0131                   | 4877                            | 3777                            | 1.047                                                                 | 7385                                                          | 131.4                                                      | 6492                                                                   | .0137                                            | 7,818                                                 | 6055                                                  | 1.072                                                                                             | 1498                                                                           |
| 13  | 70.5                           | .0092                   | 3098                            | 2176                            | 1.078                                                                 | 6578                                                          | 109.6                                                      | 3838                                                                   | .0097                                            | 4,941                                                 | 3471                                                  | 1.106                                                                                             | 1234                                                                           |
| 14  | 81.5                           | 0.0166                  | 5243                            | 4989                            | 0.973                                                                 | 7990                                                          | 141.3                                                      | 8848                                                                   | 0.0174                                           | 9,322                                                 | 8870                                                  | 0.997                                                                                             | 1728                                                                           |
| 15  | 79.0                           | .0154                   | 4857                            | 4857                            | .900                                                                  | 7772                                                          | 138.3                                                      | 8002                                                                   | .0161                                            | 8,694                                                 | 8694                                                  | .920                                                                                              | 1651                                                                           |
| 16  | 75.3                           | .0133                   | 4221                            | 4082                            | .882                                                                  | 7417                                                          | 130.5                                                      | 6581                                                                   | .0140                                            | 7,513                                                 | 7266                                                  | .906                                                                                              | 1519                                                                           |
| 17  | 63.4                           | .0099                   | 2713                            | 2460                            | .915                                                                  | 6574                                                          | 109.8                                                      | 4105                                                                   | .0104                                            | 4,824                                                 | 4374                                                  | .938                                                                                              | 1286                                                                           |
| 18  | 81.5                           | 0.0167                  | 6198                            | 4114                            | 1.191                                                                 | 8027                                                          | 141.2                                                      | 8906                                                                   | 0.0175                                           | 11,001                                                | 7302                                                  | 1.220                                                                                             | 1735                                                                           |
| 19  | 81.2                           | .0163                   | 6120                            | 4051                            | 1.177                                                                 | 7989                                                          | 140.8                                                      | 8712                                                                   | .0172                                            | 10,894                                                | 7211                                                  | 1.208                                                                                             | 1720                                                                           |
| 20  | 80.1                           | .0147                   | 5879                            | 3817                            | 1.110                                                                 | 7818                                                          | 138.2                                                      | 7679                                                                   | .0154                                            | 10,400                                                | 6752                                                  | 1.138                                                                                             | 1656                                                                           |
| 21  | 65.9                           | .0092                   | 3488                            | 1799                            | 1.209                                                                 | 6708                                                          | 114.6                                                      | 3966                                                                   | .0097                                            | 6,212                                                 | 3204                                                  | 1.238                                                                                             | 1234                                                                           |
| 22  | 70.0                           | 0.0178                  | 5769                            | 3723                            | 1.203                                                                 | 8602                                                          | 146.1                                                      | 11,147                                                                 | 0.0212                                           | 13,142                                                | 8481                                                  | 1.314                                                                                             | 1959                                                                           |
| 23  | 69.2                           | .0158                   | 5402                            | 3388                            | 1.160                                                                 | 8311                                                          | 144.2                                                      | 9,755                                                                  | .0188                                            | 12,290                                                | 7708                                                  | 1.266                                                                                             | 1833                                                                           |
| 24  | 66.6                           | .0135                   | 4817                            | 2860                            | 1.133                                                                 | 7834                                                          | 138.7                                                      | 7,963                                                                  | .0159                                            | 10,901                                                | 6472                                                  | 1.230                                                                                             | 1648                                                                           |
| 25  | 60.0                           | .0106                   | 3817                            | 2034                            | 1.131                                                                 | 7180                                                          | 125.8                                                      | 5,571                                                                  | .0123                                            | 8,600                                                 | 4563                                                  | 1.216                                                                                             | 1407                                                                           |
| 26  | 54.0                           | 0.0172                  | 4274                            | 2909                            | 1.148                                                                 | 8265                                                          | 141.5                                                      | 9,704                                                                  | 0.0191                                           | 11,792                                                | 8026                                                  | 1.209                                                                                             | 1846                                                                           |
| 27  | 53.7                           | .0170                   | 4157                            | 2832                            | 1.162                                                                 | 8283                                                          | 143.1                                                      | 9,875                                                                  | .0191                                            | 11,760                                                | 8012                                                  | 1.233                                                                                             | 1846                                                                           |
| 28  | 50.9                           | .0169                   | 3943                            | 2634                            | 1.173                                                                 | 8016                                                          | 139.4                                                      | 9,939                                                                  | .0179                                            | 11,096                                                | 7412                                                  | 1.206                                                                                             | 1756                                                                           |
| 29  | 49.9                           | .0156                   | 3721                            | 2423                            | 1.156                                                                 | 7784                                                          | 136.9                                                      | 8,029                                                                  | .0163                                            | 10,441                                                | 6799                                                  | 1.181                                                                                             | 1665                                                                           |
| 30  | 53.2                           | .0157                   | 4005                            | 2675                            | 1.125                                                                 | 8046                                                          | 141.7                                                      | 8,948                                                                  | .0175                                            | 11,270                                                | 7527                                                  | 1.188                                                                                             | 1751                                                                           |
| 31  | 52.0                           | .0148                   | 3785                            | 2481                            | 1.116                                                                 | 7806                                                          | 139.5                                                      | 8,183                                                                  | .0163                                            | 10,651                                                | 6982                                                  | 1.172                                                                                             | 1672                                                                           |
| 32  | 49.6                           | .0134                   | 3484                            | 2223                            | 1.079                                                                 | 7548                                                          | 133.9                                                      | 7,094                                                                  | .0147                                            | 9,830                                                 | 6280                                                  | 1.130                                                                                             | 1570                                                                           |
| 33  | 46.8                           | .0131                   | 3086                            | 1843                            | 1.196                                                                 | 7280                                                          | 128.1                                                      | 6,223                                                                  | .0135                                            | 8,527                                                 | 5125                                                  | 1.214                                                                                             | 1474                                                                           |
| 34  | 44.1                           | .0105                   | 2603                            | 1473                            | 1.131                                                                 | 6927                                                          | 119.9                                                      | 4,877                                                                  | .0113                                            | 7,343                                                 | 4155                                                  | 1.174                                                                                             | 1338                                                                           |
| 35  | 32.2                           | 0.0167                  | 2559                            | 1632                            | 1.183                                                                 | 8108                                                          | 142.3                                                      | 9,473                                                                  | 0.0185                                           | 11,927                                                | 7607                                                  | 1.246                                                                                             | 1795                                                                           |
| 36  | 31.8                           | .0164                   | 2512                            | 1609                            | 1.168                                                                 | 8011                                                          | 140.2                                                      | 9,167                                                                  | .0181                                            | 11,656                                                | 7466                                                  | 1.227                                                                                             | 1780                                                                           |
| 37  | 29.2                           | .0143                   | 2139                            | 1288                            | 1.165                                                                 | 7547                                                          | 131.6                                                      | 7,389                                                                  | .0156                                            | 10,081                                                | 6070                                                  | 1.218                                                                                             | 1596                                                                           |
| 38  | 29.3                           | .0127                   | 2010                            | 1179                            | 1.137                                                                 | 7349                                                          | 128.6                                                      | 6,561                                                                  | .0141                                            | 9,326                                                 | 5471                                                  | 1.200                                                                                             | 1519                                                                           |
| 39  | 25.9                           | .0112                   | 1554                            | 809                             | 1.298                                                                 | 6903                                                          | 118.8                                                      | 5,137                                                                  | .0120                                            | 7,357                                                 | 3830                                                  | 1.341                                                                                             | 1355                                                                           |
| 40  | 25.4                           | 0.0167                  | 2024                            | 1242                            | 1.232                                                                 | 8093                                                          | 145.0                                                      | 9,745                                                                  | 0.0186                                           | 12,203                                                | 7488                                                  | 1.302                                                                                             | 1819                                                                           |
| 41  | 24.9                           | .0161                   | 1875                            | 1154                            | 1.249                                                                 | 7966                                                          | 139.4                                                      | 9,088                                                                  | .0181                                            | 11,145                                                | 6859                                                  | 1.325                                                                                             | 1770                                                                           |
| 42  | 23.9                           | .0148                   | 1773                            | 1044                            | 1.216                                                                 | 7639                                                          | 134.8                                                      | 8,007                                                                  | .0166                                            | 10,569                                                | 6223                                                  | 1.286                                                                                             | 1652                                                                           |
| 43  | 23.0                           | .0130                   | 1568                            | 844                             | 1.216                                                                 | 7367                                                          | 129.9                                                      | 6,803                                                                  | .0146                                            | 9,372                                                 | 5284                                                  | 1.287                                                                                             | 1548                                                                           |
| 44  | 21.8                           | .0114                   | 1453                            | 777                             | 1.148                                                                 | 7059                                                          | 120.6                                                      | 5,530                                                                  | .0142                                            | 8,516                                                 | 4554                                                  | 1.352                                                                                             | 1430                                                                           |



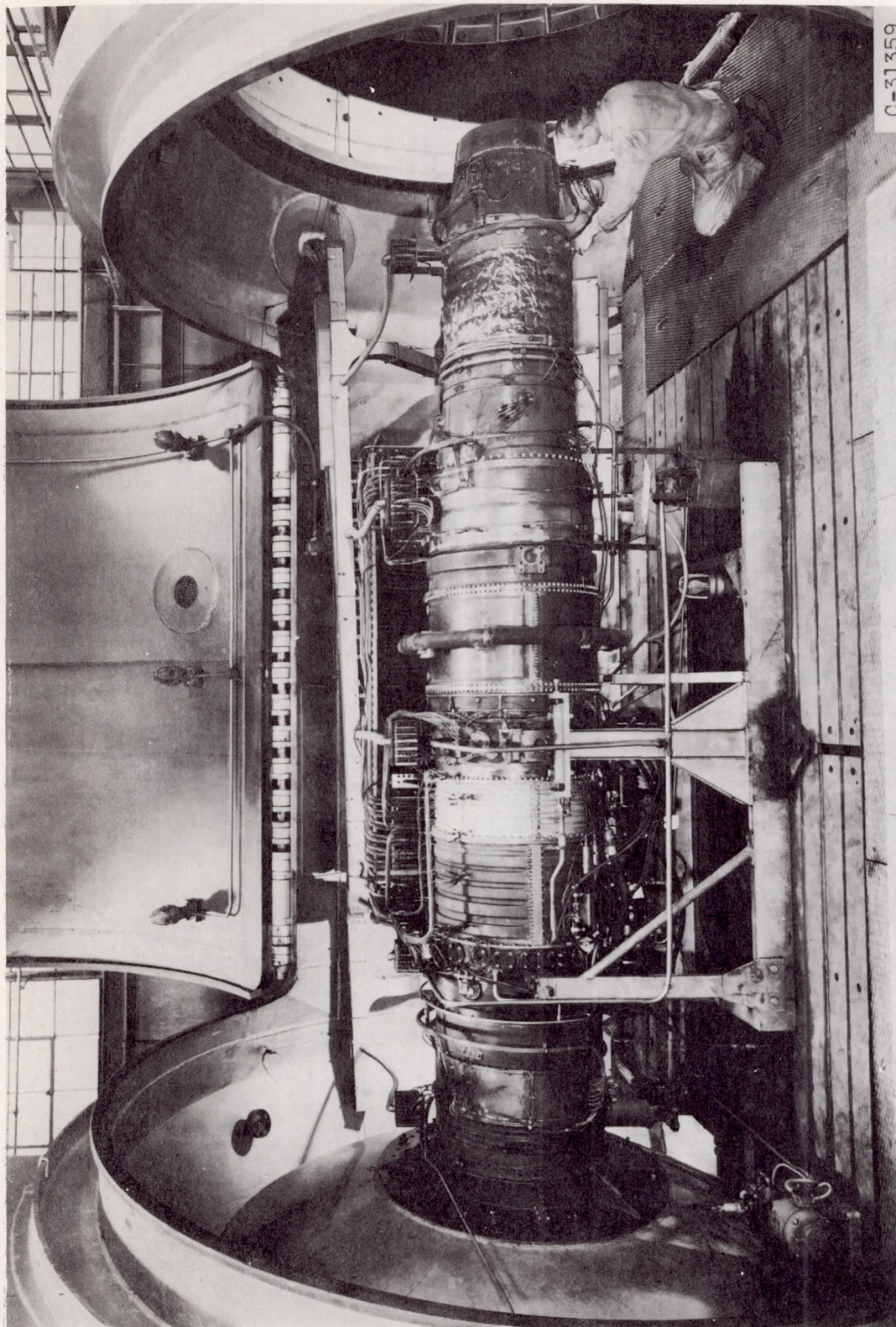


Figure 1. - View of J73-GE-1A engine in altitude chamber.



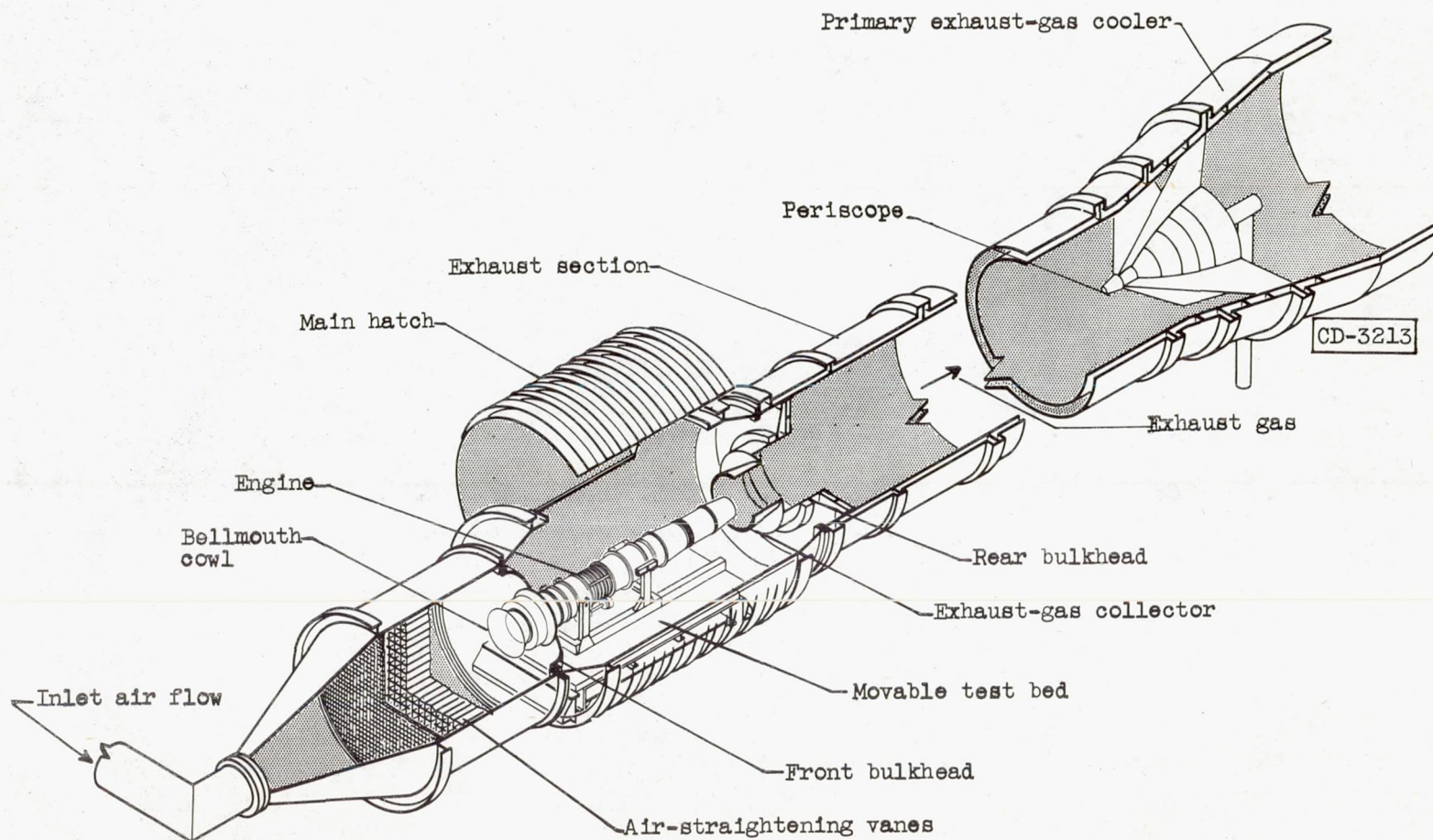
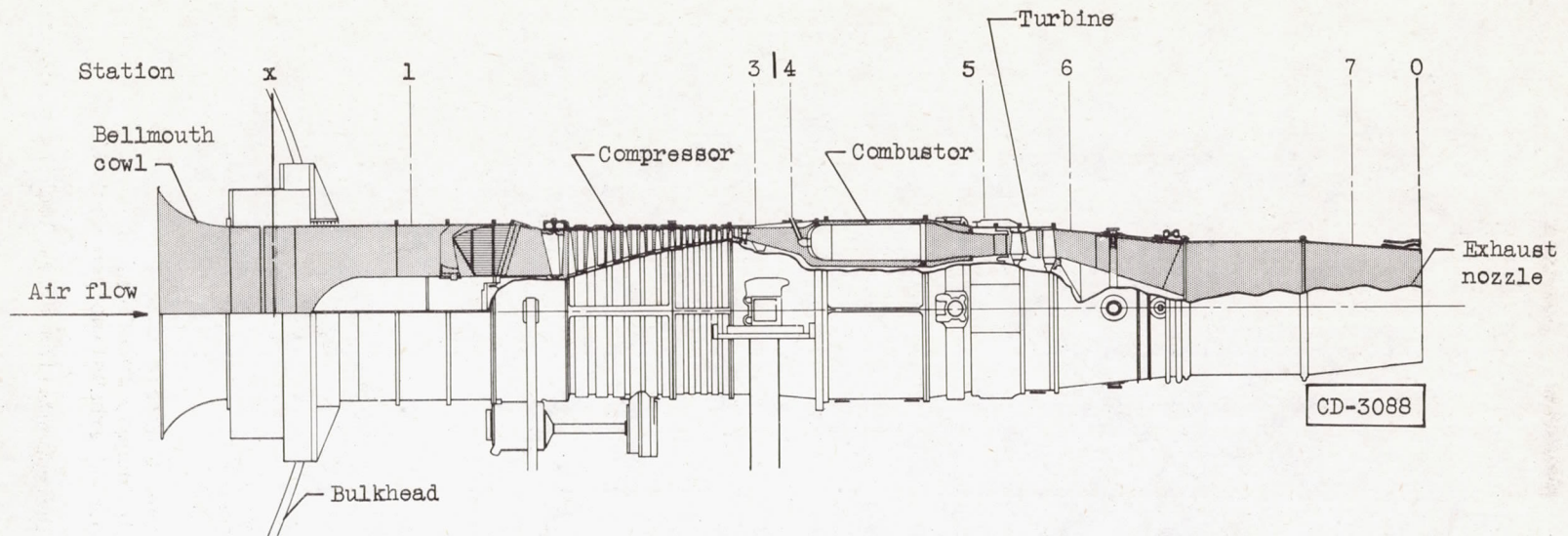


Figure 2. - Altitude chamber with engine installed in test section.

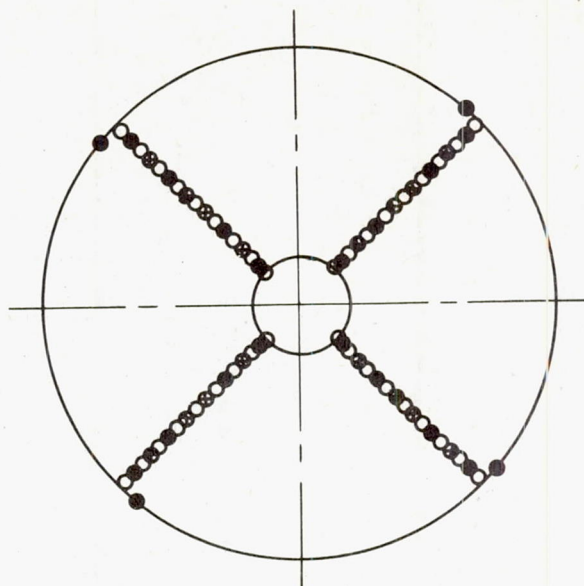




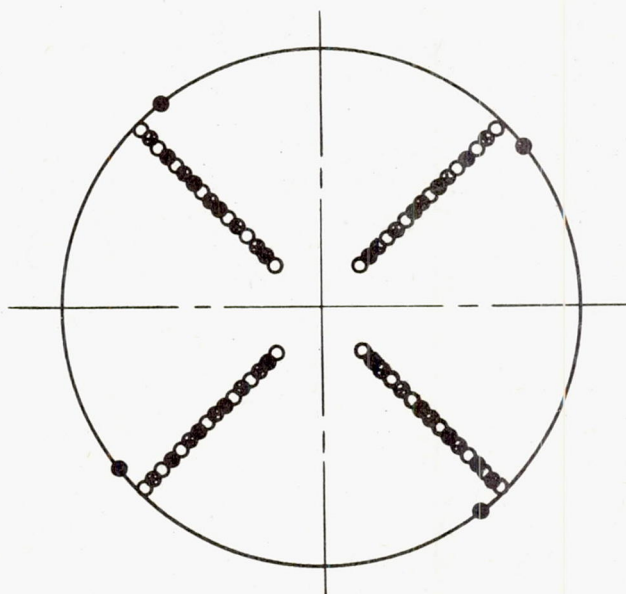
| Station | Location              | Total-pressure tubes | Static-pressure tubes | Wall static-pressure orifices | Thermo-couples |
|---------|-----------------------|----------------------|-----------------------|-------------------------------|----------------|
| x       | Engine-inlet duct     | 0                    | 0                     | 4                             | 0              |
| 1       | Engine inlet          | 36                   | 16                    | 4                             | 16             |
| 3       | Compressor outlet     | 20                   | 4                     | 5                             | 6              |
| 4       | Combustor inlet       | 10                   | 0                     | 0                             | 0              |
| 5       | Turbine inlet         | 9                    | 0                     | 0                             | 0              |
| 6       | Turbine outlet        | 24                   | 0                     | 8                             | 20             |
| 7       | Exhaust nozzle        | 28                   | 16                    | 4                             | 20             |
| 0       | Altitude test chamber | 0                    | 4                     | 0                             | 0              |

Figure 3. - Side view of turbojet engine showing instrumentation stations.

- Total pressure
- Static pressure
- ⊗ Thermocouple



(a) Station 1, engine inlet. Passage height, 9.8 inches; location, 37 inches upstream of inlet guide vanes.



(b) Station 7, exhaust-nozzle inlet. Diameter, 23.5 inches; location, 11.8 inches upstream of exhaust-nozzle outlet.

Figure 4. - Location of instrumentation (view looking downstream).



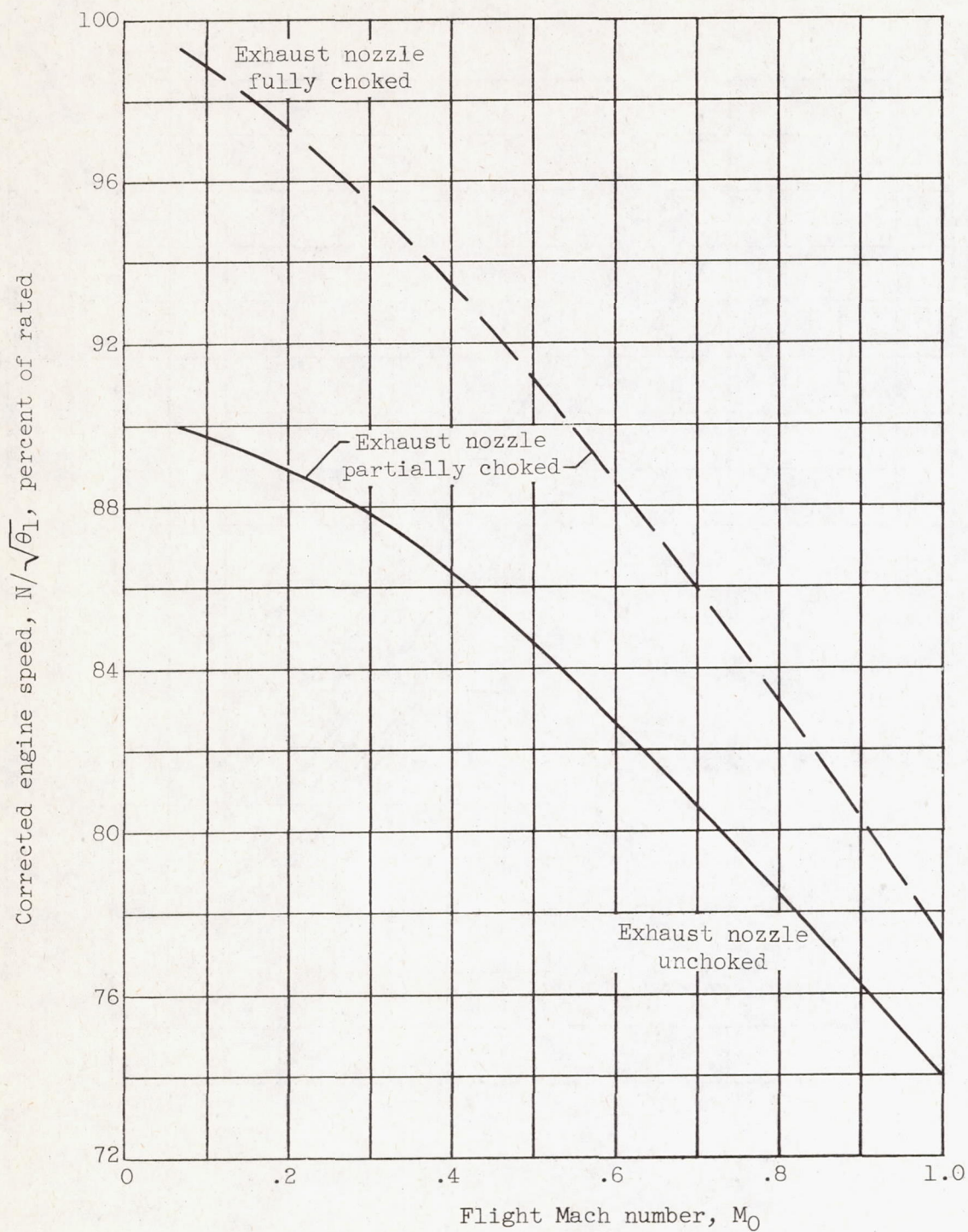


Figure 5. - Operating conditions required to choke exhaust nozzle.

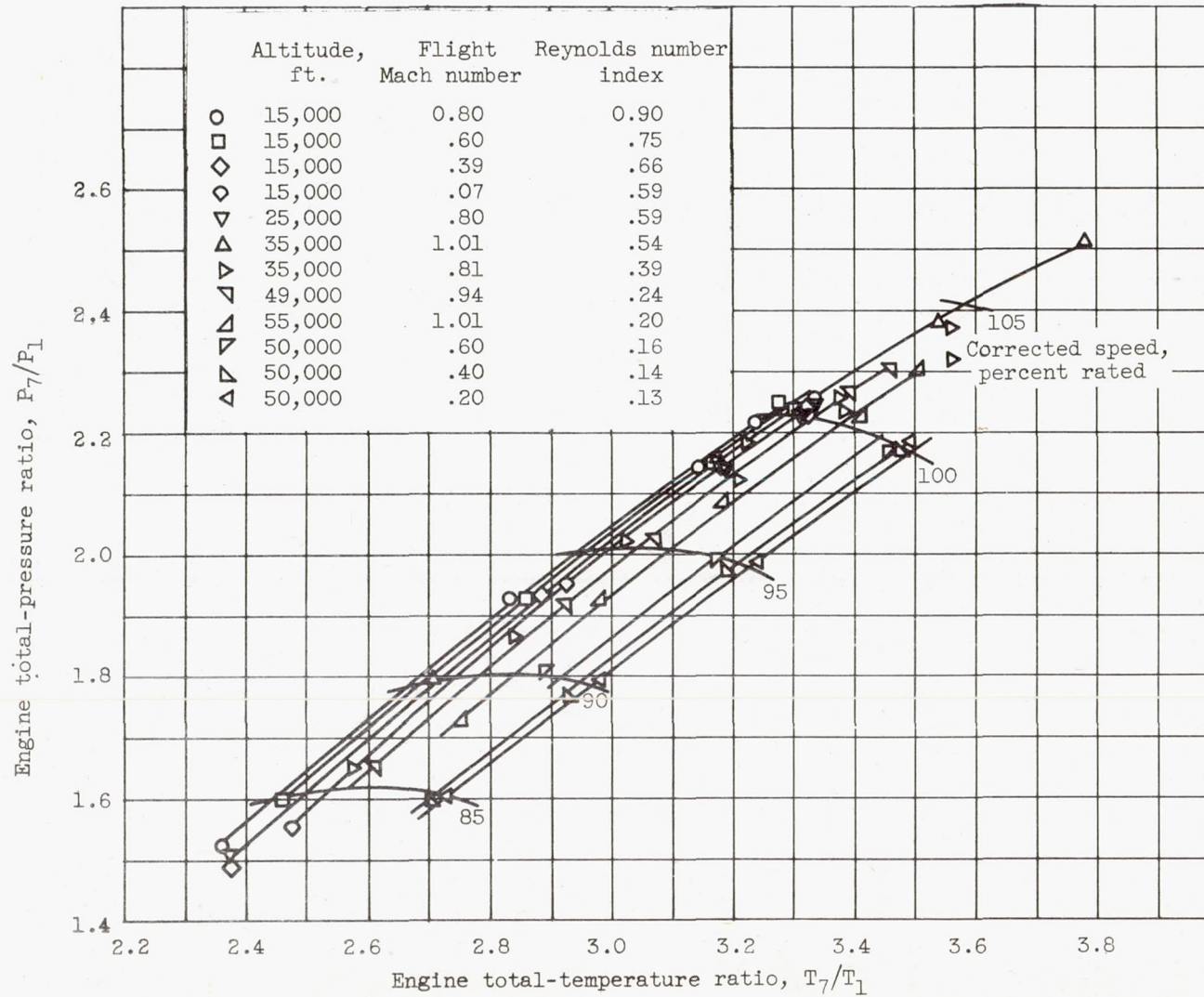


Figure 6. - Engine pumping characteristics. Exhaust-nozzle area, 345 square inches.



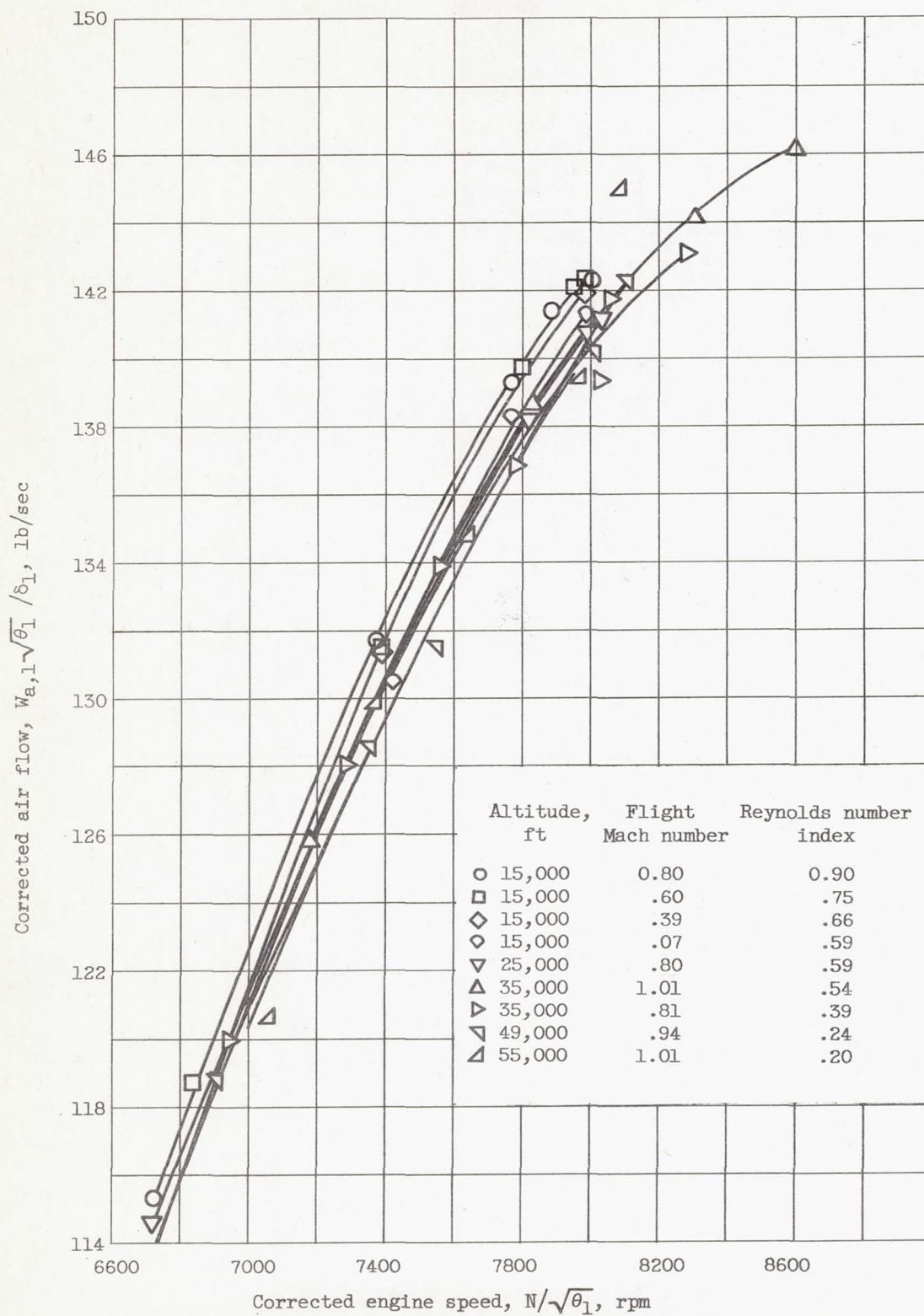


Figure 7. - Effect of Reynolds number index on engine air flow.

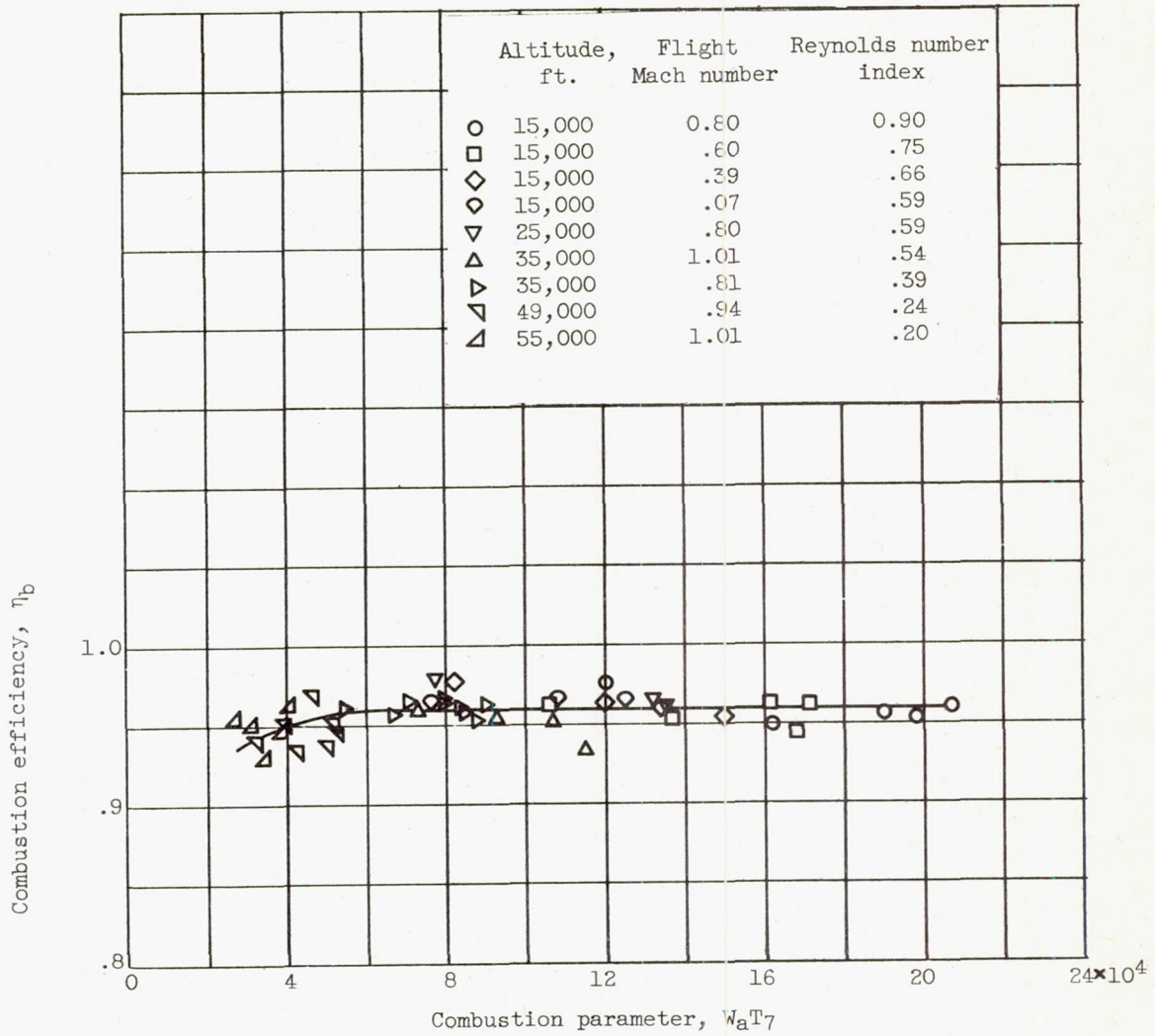


Figure 8. - Variation of engine combustion efficiency with combustion parameter.



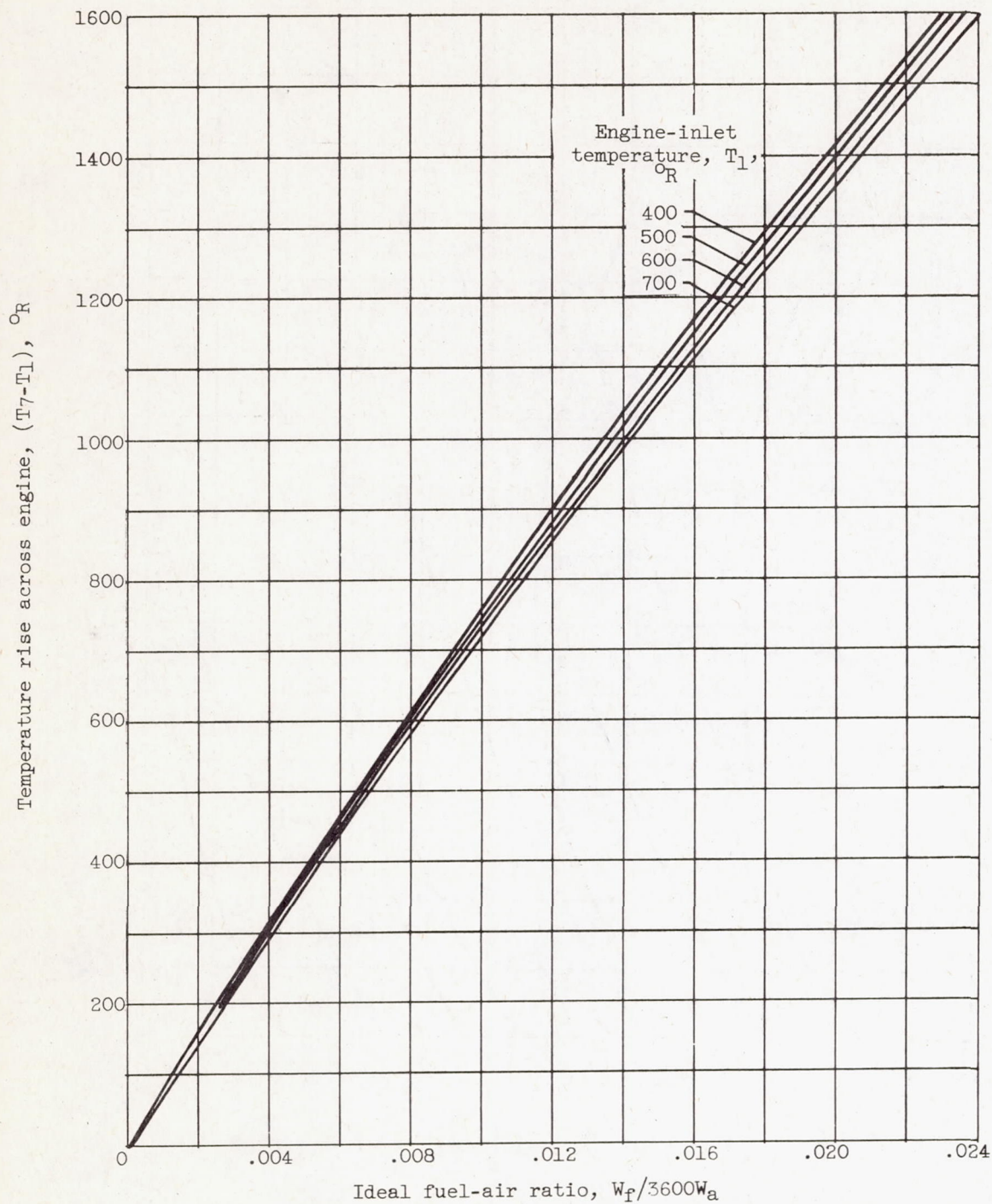


Figure 9. - Engine temperature rise as function of ideal fuel-air ratio. Lower heating value, 18,700 Btu per pound; hydrogen-carbon ratio, 0.171. (Data obtained from ref. 3).

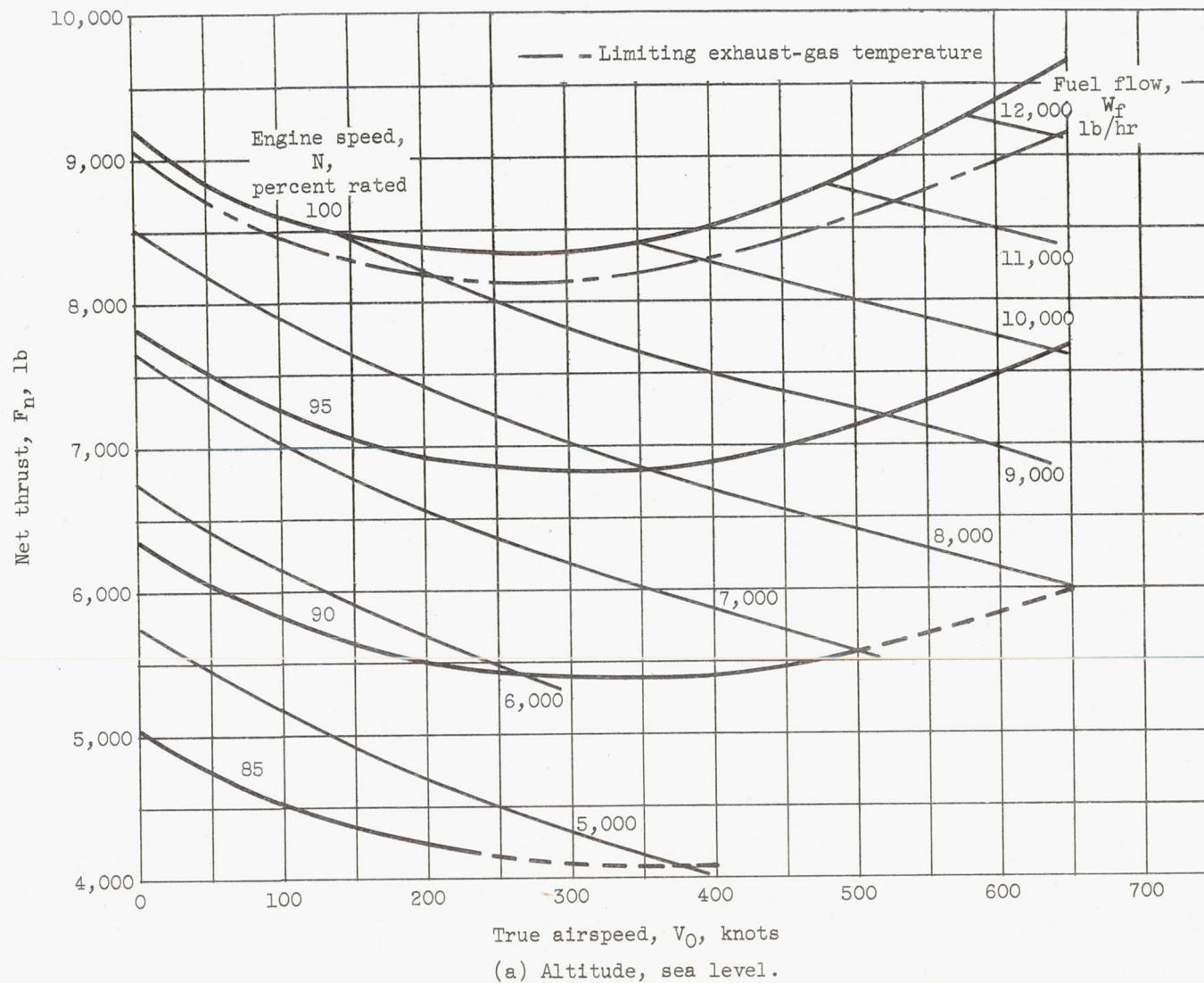


Figure 10. - Variation of net thrust and fuel flow with true airspeed.



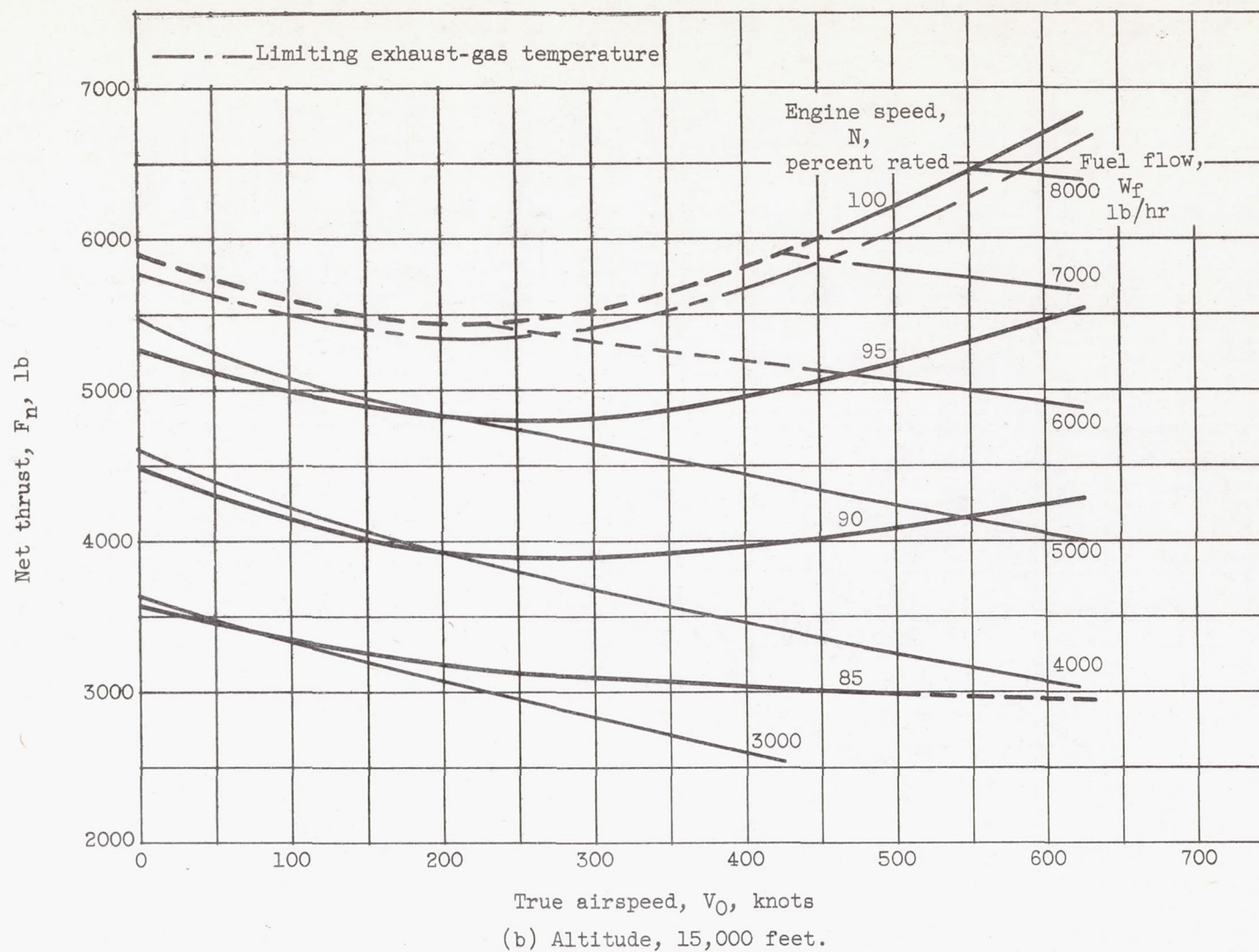


Figure 10. - Continued. Variation of net thrust and fuel flow with true airspeed.

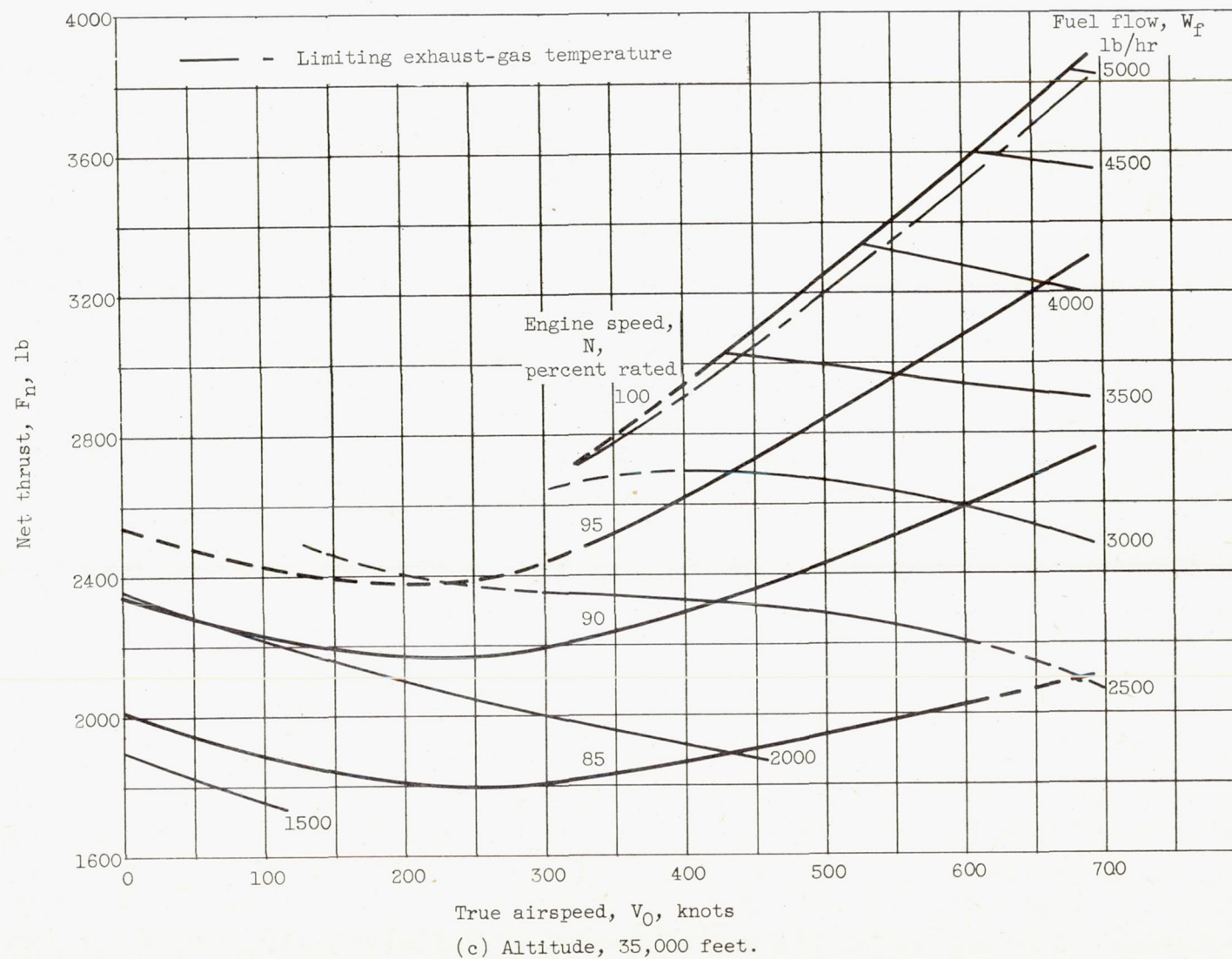


Figure 10. - Continued. Variation of net thrust and fuel flow with true airspeed.



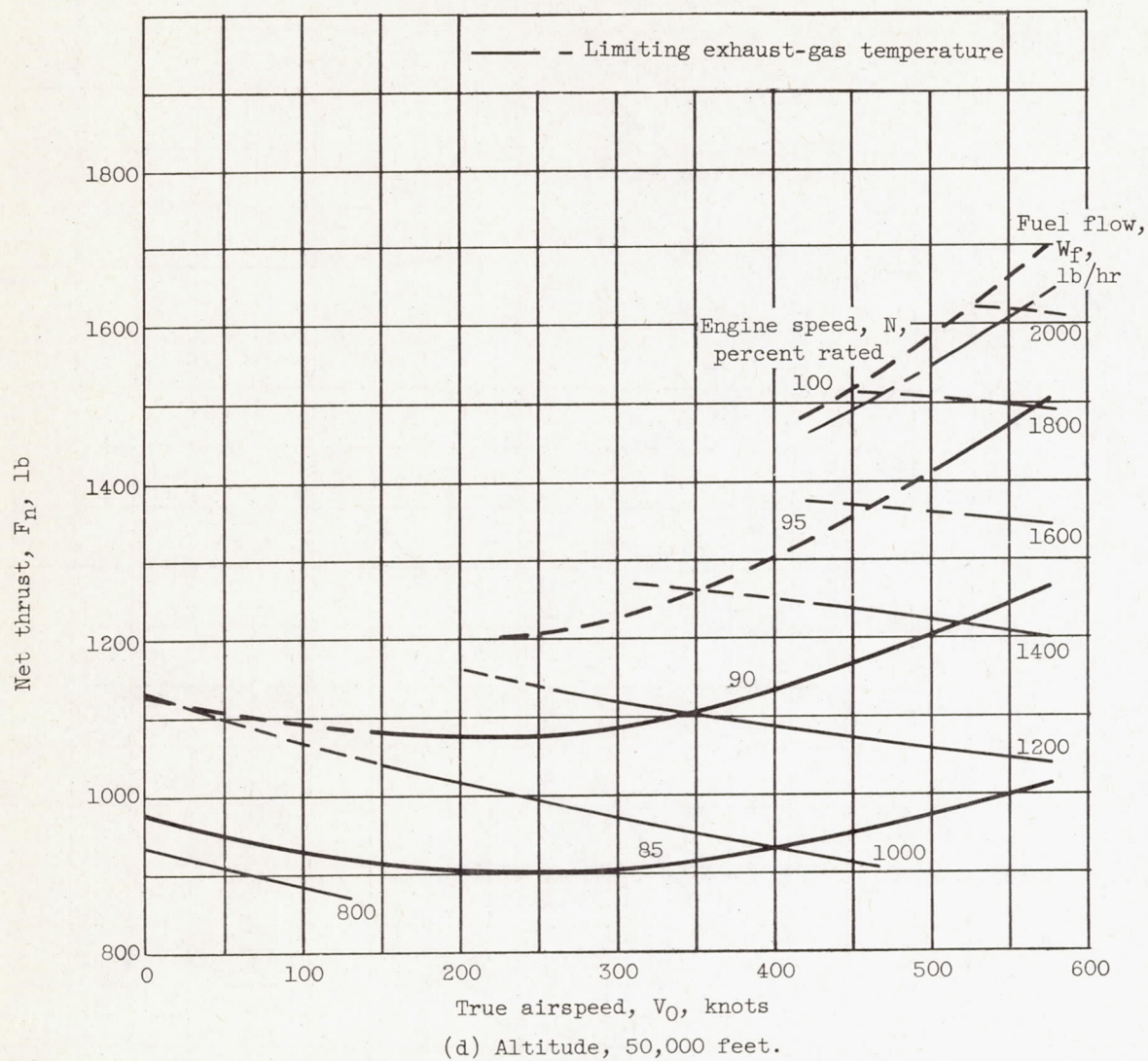


Figure 10. - Concluded. Variation of net thrust and fuel flow with true airspeed.

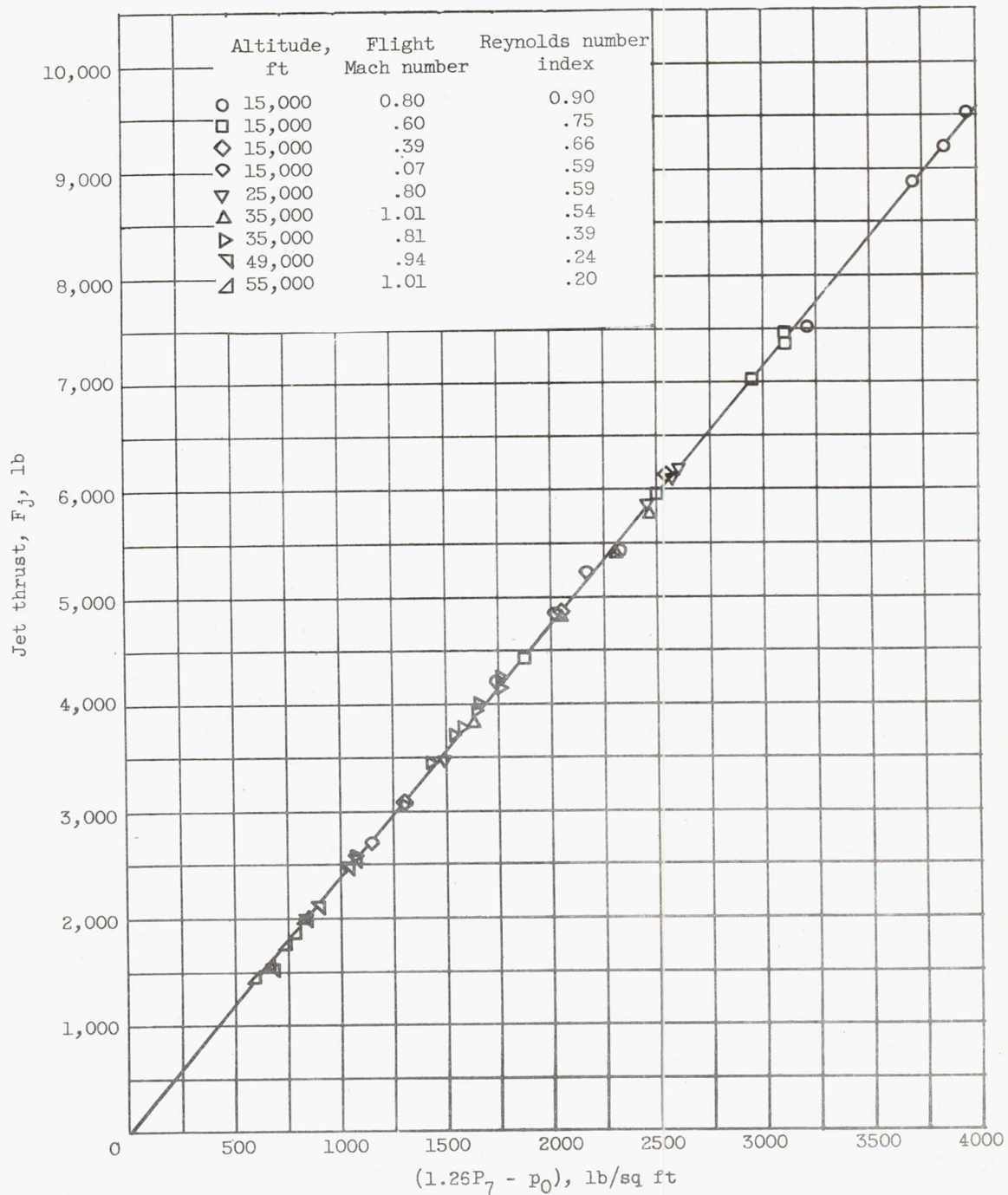
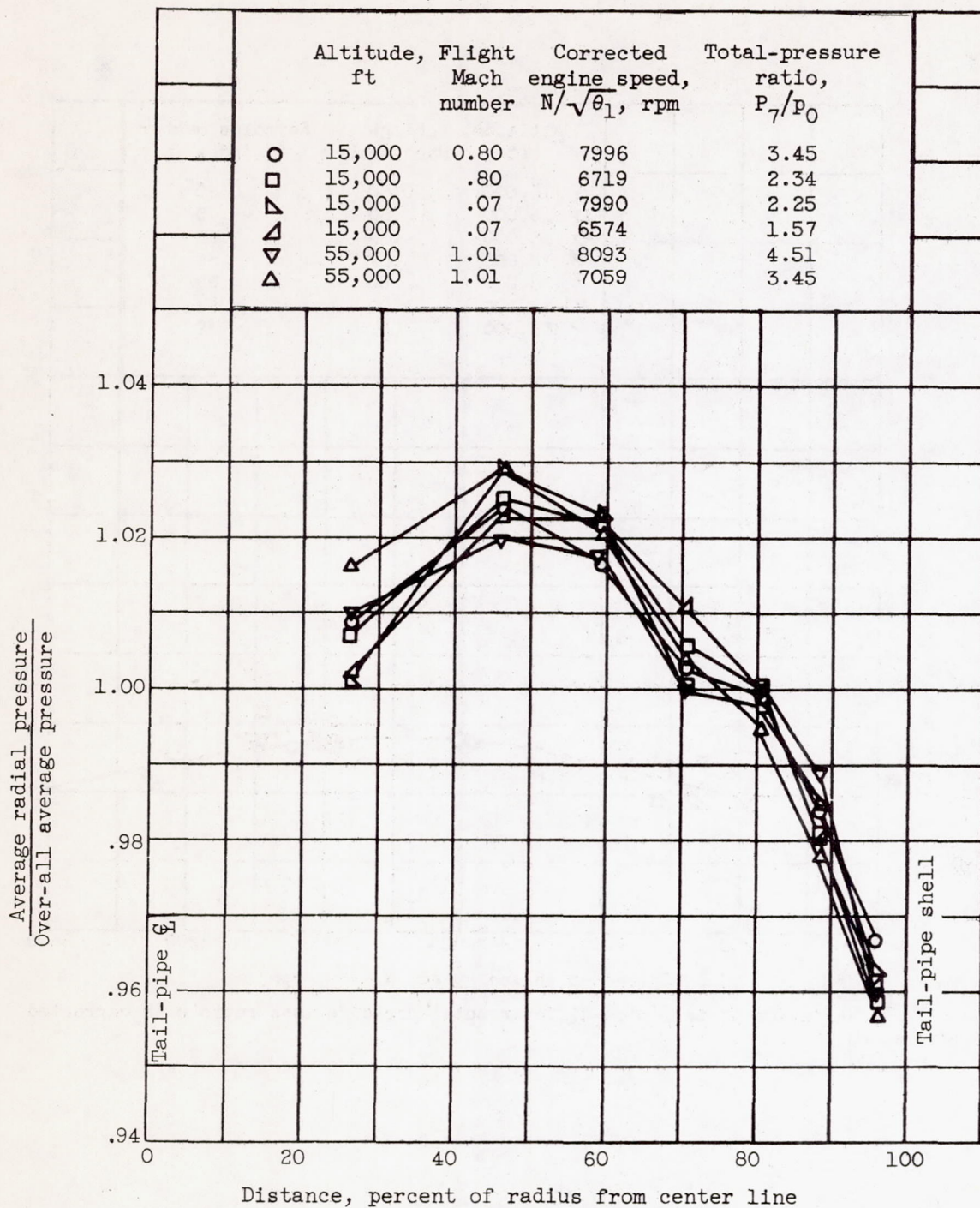


Figure 11. - Correlation of jet thrust with exhaust-nozzle total pressure and ambient static pressure.





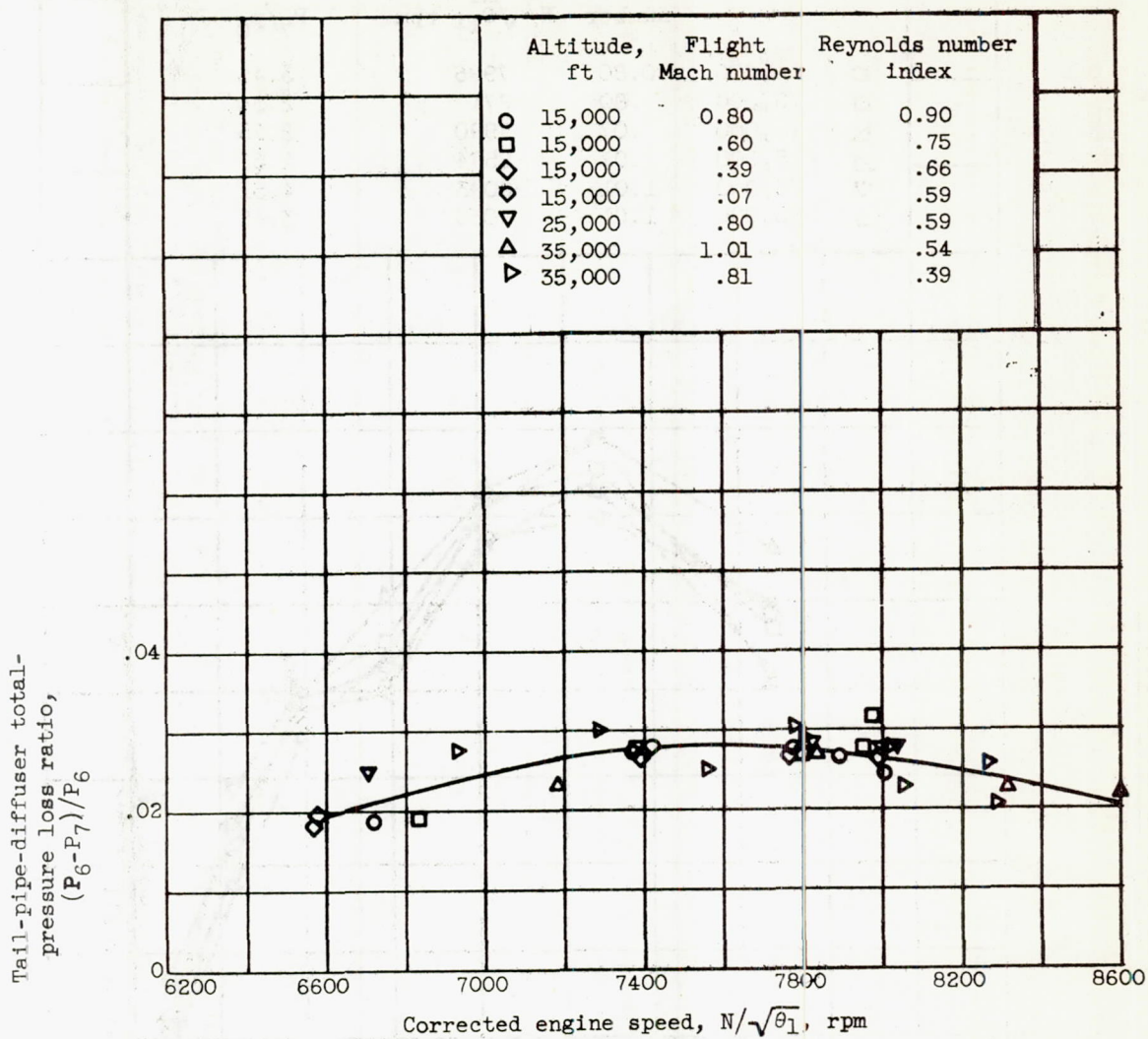


Figure 13. - Variation of tail-pipe-diffuser total-pressure loss ratio with corrected engine speed.